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### (54) THIN FILM TRANSISTOR

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CPC .... H01L 29/78654 (2013.01); H01L 29/78696 (2013.01); H01L 51/0048 (2013.01); H01L 29/0673 (2013.01); H01L 51/0508 (2013.01); H01L 29/413 (2013.01); B82Y 10/00 (2013.01)

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CPC ...... H01L 27/12; H01L 27/1214; H01L 29/66757; H01L 29/66765; H01L 29/78696 USPC ...... 257/27, 57, E29.299, E21.414 See application file for complete search history.

### **References Cited** (56)

### U.S. PATENT DOCUMENTS

4,354,162 A 10/1982 Wright 4,758,831 A 7/1988 Kasahara et al. (Continued)

### FOREIGN PATENT DOCUMENTS

1294034 1/1992 CA CA 2109951 11/1992 (Continued)

### OTHER PUBLICATIONS

European Search Report and Written Opinion for Application No. 08 86 5338 mailed Nov. 2, 2011 (7 pages).

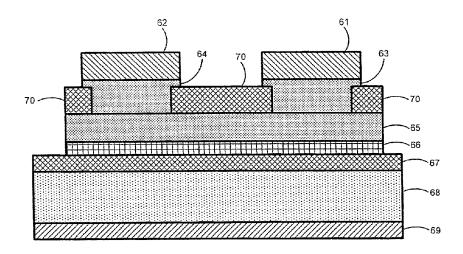
(Continued)

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#### (57)ABSTRACT

A thin film transistor comprises a semiconductor layer; first and second dielectric layers disposed on opposite sides of the semiconductor layer; a first metal layer forming first and second terminals on the opposite side of the first dielectric layer from the semiconductor layer, one of said first and second terminals extending through said first dielectric layer into contact with the semiconductor layer, the first and second terminals and the first dielectric layer forming a capacitor; and a second metal layer forming a third terminal on the opposite side of the second dielectric layer from the semiconductor layer. The first and second terminals may be source and drain terminals, and the third terminal may be a gate terminal. The first metal layer may be divided to form the first and second terminals. The third terminal may be shared with one of the first and second terminals.

### 6 Claims, 6 Drawing Sheets



# US 9,070,775 B2 Page 2

Company								
BBIL 51/95	(51)	Int. Cl.			6,501,098	B2	12/2002	Yamazaki
Holl. 51/05   C2006.01   C512.271   Bl 2   22003   Yamazzik et al.	` '	H01L 29/06		(2006.01)	6,501,466	B1	12/2002	Yamagishi et al.
BBSY 1000				` /	6,512,271	B1		
HOLL 51/00   (2006.01)				,	6,518,594	B1	2/2003	Nakajima et al.
March   Content   Conten				` /	6,524,895	B2	2/2003	Yamazaki et al.
(56) References Cited		H01L 51/00		(2006.01)				
Company		H01L 29/41		(2006.01)	6,559,594	B2	5/2003	Fukunaga et al.
U.S. PATENT DOCUMENTS				(	6,573,195	B1	6/2003	Yamazaki et al.
U.S. PATENT DOCUMENTS	(56)		Dofowor	oog Citod	6,573,584	B1	6/2003	Nagakari et al.
1.5   1.5	(30)		Kelefell	ices Cheu	6,576,926	B1		
4.963,860 A   10/1990   Stewart   6.388,775 E   6.200   Skinya et al.		HC	DATENIT	DOCHMENTS	6,580,408	B1	6/2003	Bae et al.
4.963,860 A 1 (21)990 Stewart 6,583,776 B2 6/2003 Yamazaki et al. 4.975,091 A2 (21)991 Bell et al. 6,593,691 B2 7,2003 Nishi et al. 5,091,739 A 9 (19)91 Hayashi et al. 6,593,691 B2 7,2003 Nishi et al. 5,091,739 A 9 (19)91 Hayashi et al. 6,597,201 B2 7,2003 Nishi et al. 5,200,406 B2 7,2003 Nishi et al. 5,200,406 B2 7,2003 Nishi et al. 6,11,108 B2 8,2003 Kimura (19), 10, 10, 10, 10, 10, 10, 10, 10, 10, 10		U.S.	PAIENI	DOCUMENTS	6,580,657	B2	6/2003	Sanford et al.
4.975.691   A 12/1990   Lee   G.S.\$70.68   B1 7.2003   Koyaran et al.   5.051.739   A 9/1991   Hayashida et al.   G.S.\$3,691   B2 7.2003   Everiti   5.222.082   A 6/1993   Phis   G.594.666   B2 7.2003   Everiti   5.222.082   A 6/1993   Phis   G.597.203   B2 7.2003   Everiti   5.222.082   A 6/1993   Phis   G.597.203   B2 7.2003   Everiti   5.222.082   A 6/1993   Robb et al.   G.611.108   B2 8.2003   Kimura   5.408.880   A 3/1996   Lee et al.   G.611.408   B2 8.2003   Kimura   5.408.880   A 4/1999   Weisfield   G.641.933   B1 1/12003   Yamazaki et al.   6.670.0373   A 4/1999   Weisfield   G.641.933   B1 1/12003   Yamazaki et al.   6.661.803   B2 1/22003   Kimura   6.670.0373   A 7/1998   Hara et al.   G.661.180   B2 1/22003   Mismit et al.   6.670.0373   B2 1/22003   Yamazaki et al.   6.670.0373   B2 1/22004   Balmon et al.   6.770.0383   B2 1/22004   Balmon et al.   6.770.		4.062.060.4	10/1000	Ct.	6,583,775	В1		
4.996,523 A					6,583,776	B2	6/2003	Yamazaki et al.
5.051,739 A   6/1991   Hayashida et al.   6.594,666   812   7.2003   Eventral S.   5.220,66.51					6,587,086	B1	7/2003	Koyama
5,222,082 A 6/1993 Phis					6,593,691	B2	7/2003	Nishi et al.
5,266,515					6,594,606	B2	7/2003	Everitt
5,498,880 A   3/1996   Lee et al.   6,611,644   Bi   9,2003   Sammaraki et al.   5,598,847 A   12/1996   Lewis   6,618,030   Bi   12/2003   Sammaraki et al.   5,648,276 A   7/1997   Hara et al.   6,661,180   Bi   2,12003   Sammaraki et al.   5,648,276 A   7/1997   Hara et al.   6,661,180   Bi   2,12003   Sammaraki et al.   5,688,276 A   7/1997   Weisbrod   6,670,637 Bi   12/2004   Mikami et al.   5,768,6935 A   11/1998   Ricda   6,670,637 Bi   12/2004   Mikami et al.   5,714,968 A   2/1998   Ricda   6,680,577 Bi   12/2004   Mukai et al.   5,748,106 A   5/1998   Shake et al.   6,680,576 Bi   12/2004   Mac et al.   5,748,106 A   5/1998   Shich et al.   6,690,344 Bi   2/2004   Mac et al.   5,748,106 A   5/1998   Shich et al.   6,693,361 Bi   2/2004   Mac et al.   5,748,106 A   5/1998   Matsuyama   6,693,610 Bi   2/2004   Mac et al.   5,709,234 A   8/1998   Matsuyama   6,693,610 Bi   2/2004   Mac et al.   5,870,071 A   2/1999   Rivabata   6,729,428 E   2/2004   Sammor et al.   5,870,071 A   2/1999   Sawada   6,734,636 Bi   2/2004   Sammor et al.   5,870,387 A   3/1999   Sawada   6,738,303 Bi   2/2004   Sammor et al.   5,870,332 A   3/1999   Sawada   6,738,303 Bi   2/2004   Sammor et al.   5,900,629 A   1/1999   Sawada   6,738,303 Bi   2/2004   Sammor et al.   5,900,629 A   1/1999   Sawada   6,738,303 Bi   2/2004   Sammor et al.   6,777,712 Bi   2/2004   Vinters   5,900,629 A   1/1999   Sawada   6,738,303 Bi   2/2004   Samford et al.   6,709,329 A   2/2009   Sawada   6,738,303 Bi   2/2004   Samford et al.   6,709,329 A   2/2009   Sawada   6,738,303 Bi   2/2004   Samford et al.   6,709,329 A   2/2009   Sawada   6,738,303 Bi   2/2004   Sambor et al.   6,709,329 A   2/2009   Sawada   6,738,303 Bi   2/2004   Sambor et al.   6,709,329 A   2/2009   Sawada   6,738,303 Bi   2/2004   Sambor et al.   6,709,329 Bi   2/2004   Sambor et al.   6,709,329 Bi   2/2004   Sambor et al.   6,709,329 Bi   2/2004   Sambor et al.   6,809,329 Bi   2/2004   Sambor et al.   6,809,329 Bi   2/2004   Sambor et al.   6,909,329 Bi   2/2004   Sam					6,597,203	B2	7/2003	Forbes
5,589,847 A 12/1996 Lewis 66,618-70 B 2 2008 Rance et al. 5,619,033 A 4/1997 Weisfield 66,4193 B 1 2008 Yamazaki et al. 5,670,073 A 7/1997 Bassetti et al. 6,661,130 B 2 12/2003 Yamazaki et al. 5,670,073 A 7/1997 Bassetti et al. 6,661,130 B 2 12/2003 Yamazaki et al. 5,670,073 A 7/1997 Bassetti et al. 6,661,130 B 2 12/2003 Yamazaki et al. 5,670,073 A 7/1997 Bassetti et al. 6,661,130 B 2 12/2003 Yamazaki et al. 5,741,068 A 2/1998 Katoh et al. 6,671,713 B 12/2004 Inuxia et al. 5,741,068 A 2/1998 Shanks et al. 6,677,713 B 12/2004 Inuxia et al. 5,744,062 A 7/1998 Shanks et al. 6,680,577 B 1 12/2004 Inuxia et al. 5,784,042 A 7/1998 Marks et al. 6,680,338 B 2/2004 Omura 5,790,234 A 7/1998 Berlin 6,693,388 B 2/2004 Omura 5,815,303 A 9/1998 Berlin 6,693,610 B 2/2004 Shannon et al. 5,815,303 A 9/1998 Berlin 6,697,057 B 2/2004 Shannon et al. 5,874,803 A 2/1999 Garbuzov et al. 6,734,636 B 2/2004 Vamazaki et al. 5,874,803 A 2/1999 Garbuzov et al. 6,734,636 B 2/2004 Vamazaki et al. 5,893,48 A 5/1999 Jiwin 6,738,035 B 5/2004 F al. 5,993,248 A 5/1999 Jiwin 6,738,035 B 5/2004 Kaneko et al. 5,993,248 A 5/1999 Jiwin 6,738,035 B 5/2004 Kaneko et al. 6,771,712 B 2 8/2004 Vamazaki et al. 6,993,557 A 7/1999 Jiwin 6,738,035 B 1/2004 F al. 5,993,2789 A 7/1999 Jiwin 6,738,035 B 1/2004 F al. 5,993,678 A 7/1999 Jiwin 6,738,035 B 1/2004 Vinters 5/23,794 A 7/1999 Jiwin 6,738,035 B 1/2004 Vinters 6/23,259 A 7/1999 Jiwin 6,738,035 B 1/2004 Vinters 6/23,259 A 7/1999 Jiwin 6,738,035 B 1/2004 Vinters 6/23,259 A 1/1999 Jiwin 6,738,035 B 1/2004 Vinters 6/23,259 A 1/1999 Jiwin 6,738,035 B 1/2004 Vinters 6/23,2500 Howard et al. 6,806,638 B 2 10/2004 Vinters 6/23,2500 Howard et al. 6,806,638 B 2 10/2004 Vinters 6/23,2500 Howard et al. 6,806,638 B 2 10/2004 Vinters 6/23,236 B 1/2000 Holloman 6,873,117 B 2/2005 Vinterod 6/23,238 B 1/2000 Holloman 6,995,519 B 2/2005 Vinterod 6/23,236 B 1/2000					6,611,108	B2		
Sell					6,617,644	В1		
S,648,276 A   7/1997   Hara et al.   6,661,180 B   12,2003   Koyama   5,670,973 A   9/1997   Bassetti et al.   6,661,397 B2   12,2003   Mikami et al.   5,712,653 A   1/1998   Katoh et al.   6,670,637 B1   12,2004   Sung   5,714,968 A   2/1998   Katoh et al.   6,677,671 B   1/2004   Sung   5,714,978 A   5/1998   Shanks et al.   6,687,266 Bl   2,2004   Mac et al.   5,744,928 A   5/1998   Shanks et al.   6,687,266 Bl   2,2004   Mac et al.   5,734,160 A   5/1998   Shanks et al.   6,693,348 Bl   2,2004   Mac et al.   5,790,234 A   5/1998   Meltin   6,693,361 Bl   2,2004   Mac et al.   5,790,234 A   5/1998   Meltin   6,693,361 Bl   2,2004   Mac et al.   5,874,803 A   2/1999   Meltin   6,693,361 Bl   2,2004   Mac et al.   5,874,803 A   2/1999   Garburov et al.   6,677,0975 Bz   2,2004   Koyama et al.   5,874,803 A   2/1999   Garburov et al.   6,720,942 Bl   2,2004   Meltin   5,893,248 A   5/1999   Inviin   6,738,034 Bl   5,2004   Sandond et al.   5,903,248 A   5/1999   Inviin   6,738,034 Bl   5,2004   Sandond et al.   5,903,248 A   5/1999   McGrath et al.   6,777,102 Bl   8,2004   Miters   5,903,249 A   7/1999   McGrath et al.   6,777,102 Bl   8,2004   Miters   5,903,249 A   7/1999   McGrath et al.   6,777,102 Bl   8,2004   Miters   5,903,249 A   7/1999   McGrath et al.   6,777,102 Bl   8,2004   Miters   5,903,259 A   2,2000   Howard et al.   6,806,638 Bl   2,0004   Miters   5,903,259 A   2,2000   Miters   6,809,706 Bl   10,0004   Miters   6,809,808   10,000   Miters   6,909,114 Bl   6,000   Miters   6,909,114 Bl								
5,670.973 A   9/1997   Bassetti et al.   6,661.397   B2   12,2003   Mikami et al.   5,686.935   A   11/1998   Weisbrod   6,670.637   B2   12,2003   Mikami et al.   5,714.968   A   1/1998   Reda   6,670.637   B1   1,2004   Inukai et al.   5,714.968   A   2/1998   Bleeda   6,670.637   B1   1,2004   Inukai et al.   1,674.938   A   5/1998   Shich et al.   6,687.266   B1   2,2004   Makai et al.   5,784.042   A   7/1998   One tal.   6,603.464   B1   2,2004   Thecurchi et al.   6,607.657   B2   2,2004   Thecurchi et al.   6,707.657   B2   2,2004   Thecurchi et al.   6,707.712   B2   2,2004   Thecurchi et								
Section								
5.712,653 A 1/1998 Rado et al. 6.077,713 B 1 1/2004 Sung Sung S.748,08 A 2/1998 Reda 6.687,266 B1 2/2004 Inukai et al. 5.744,08 A 5/1998 Shich et al. 6.698,776 B1 1/2004 Inukai et al. 5.744,08 A 5/1998 Shich et al. 6.698,766 B1 2/2004 Ma et al. 5.748,042 A 7/1998 One et al. 6.693,361 B2 2/2004 Takeuchi et al. 5.759,024 A 8/1998 Matsuyama 6.693,361 B2 2/2004 Shannon et al. 6.570,707 A 2/1999 Rawahata 6.693,610 B2 2/2004 Shannon et al. 6.587,076 B2 2/2004 Shannon et al. 6.587,076 B2 2/2004 Shannon et al. 6.590,071 A 2/1999 Rawahata 6.728,036 B2 5/2004 Shannon et al. 6.590,071 A 2/1999 Rawahata 6.738,033 B2 5/2004 Koyana et al. 6.738,033 B2 5/2004 Koyana et al. 6.738,033 B2 5/2004 Koyana et al. 6.738,033 B1 5/2004 Sanford et al. 6.738,033 B1 5/2004 Kaneko et al. 6.777,1028 B1 8/2004 Winters 5/203,7594 A 7/1999 McGrath et al. 6.777,1028 B1 8/2004 Winters 5/203,7594 A 7/1999 McGrath et al. 6.779,1028 B1 8/2004 Winters 5/203,7594 A 7/1999 McGrath et al. 6.798,078 B2 8/2004 Winters 6/203,259 A 1/1999 Yamada et al. 6.798,078 B2 8/2004 Winters 6/203,259 A 2/2000 Howard et al. 6.806,638 B2 10/2004 Samford et al. 6.806,638 B2 10/2004 Shimoda 6/091,203 A 7/2000 Kowand et al. 6.809,708 B2 10/2004 Shimoda 6/091,203 A 7/2000 Kowand et al. 6.809,708 B2 10/2004 Shimoda 6/203,239 A 1/1999 Warmada et al. 6.838,0708 B2 10/2004 Shimoda 6/203,239 B1 5/2001 Kim et al. 6.873,320 B2 2/2005 Windoo 6/203,239 B1 5/2001 Kim et al. 6.798,718 B2 2/2005 Shakamura 6/203,838 B1 2/2005 Holloman 6.873,117 B2 3/2005 Shakamura 6/203,838 B1 2/2001 Holloman 6.873,117 B2 3/2005 Shakamura 6/203,838 B1 2/2001 Holloman 6.873,117 B2 3/2005 Shakamura 6/203,838 B1 2/2001 Kim et al. 6.998,510 B2 2/2006 Murakami et al. 6.203,0363 B1 1/2001 Kim et al. 6.998,510 B2 2/2006 Murakami et al. 6.203,0363 B1 1/2001 Kim et al. 6.998,510 B2 2/2006 Murakami et al. 6.203,0363 B1 1/2001 Kim et al. 6.203,0363 B1 1/2001 Kim et al. 6.203,0363 B1 1/2001 Kim et al. 6.203,0363 B								
5,714,968   A   21998   Redn   6,688,577   B   1,2094   Inukai et al.								
5,747,928 A 5/1998 Shieh et al. 6,698,7266 B1 2,2004 Ma et al. 5,784,042 A 7/1998 Shieh et al. 6,699,344 B1 2,2004 Gardieri et al. 5,784,042 A 7/1998 Matsuyama 6,693,361 B2 2,2004 Shamon et al. 6,693,610 B2 2,2004 Shamon et al. 6,693,610 B2 2,2004 Shamon et al. 6,697,071 A2 2/1999 Kawahata 6,693,610 B2 2,2004 Koyama et al. 5,870,071 A2 2/1999 Kawahata 6,720,942 B2 2,2004 Koyama et al. 6,720,942 B2 2,2004 Koyama et al. 6,736,036 B2 5,2004 Kanekoe et al. 6,737,1028 B1 8,2004 Kanekoe et al. 6,777,1028 B1 8,2004 Kanekoe et al. 6,806,638 B2 10,2004 Kanekoe et al. 6,806,638 B2 10,2004 Kanekoe et al. 6,806,638 B2 10,2004 Kanekoe et al. 6,806,708 B2 10,2004 Kanekoe et al. 6,807,308 B2 10,2004 Kanekoe et al. 6,807,308 B2 2,2005 Komiya et al. 6,205,448 B1 5,200 Kanekoe et al. 6,807,308 B2 2,2005 Komiya et al. 6,205,448 B1 5,200 Kanekoe et al. 6,205,414 B1 6,200 Kanekoe et al. 6,205,414 B1 6,		, ,						
5,748,160 A					, ,			
5.784.042 A 7/1998 One et al. 6.693.618 B2 2/2004 Omura s. 5.790.234 A 8/1998 Matsuyama 6.693.618 B2 2/2004 Omura s. 5.870.071 A 2/1999 Sarbuzov et al. 6.693.618 B2 2/2004 Koyama et al. 5.874.803 A 2/1999 Garbuzov et al. 6.720.942 B2 4/2004 Lee et al. 5.874.803 A 2/1999 Garbuzov et al. 6.738.636 B2 5/2004 Sanford et al. 5.874.803 A 2/1999 Invino 6.738.034 B2 5/2004 Sanford et al. 5.903.234 A 5/1999 Invino 6.738.035 B1 5/2004 Fan 6/738.034 B2 5/2004 Fan 6/738.035 B1 5/2005 Fan 6/738		, ,						
S.190,234 A								
S.								
5.870,071 A         2/1999 Garburove et al.         6,720,942 B2 42004 Lee et al.           5.880,582 A         3/1999 Garburove et al.         6,734,636 B2 52004 Sanford et al.           5.903,248 A         5/1999 Fuvin         6,738,034 B2 52004 Kaneko et al.           5.917,280 A         6/1999 Fuvin         6,738,035 B1 52004 Kaneko et al.           5.923,794 A         7/1999 McGrath et al.         6,771,028 B1 82004 Winters           5.990,629 A         1/1999 McGrath et al.         6,780,687 B2 82004 Nakajima et al.           6,023,259 A         2/2000 Howard et al.         6,806,638 B2 10/2004 Lib et al.           6,081,131 A         6/200 Ishi         6,806,638 B2 10/2004 Simmoda           6,091,203 A         7/2000 Kawashima et al.         6,806,670 B1 20/204 Simmoda           6,091,203 A         7/2000 Kawashima et al.         6,807,321 B2 22005 Ohami et al.           6,144,222 A         11/2000 Ho         6,873,117 B2 32005 Ohami et al.           6,157,583 A         12/2000 Sistine et al.         6,873,320 B2 32005 Nakamura           6,177,915 B1         1/2000 Ho         6,873,171 B2 32005 Ohami et al.           6,184,222 A         1/2000 Ho         6,873,320 B2 32005 Nakamura           6,177,915 B1         1/2001 Hompson et al.         6,909,419 B2 62005 Zavracky et al.           6,229,508 B1         5/2001 Kane								
5.874,803 A         2/1999 Garbuzov et al.         6,734,636 B2 52004 Sanford et al.           5.880,582 A         3/1999 Sawada         6,738,035 B1 52004 Fan           5.903,248 A         5/1999 Irwin         6,738,035 B1 52004 Fan           5.917,280 A         6/1999 Burrows et al.         6,771,028 B1 82004 Winters           5.922,794 A         7/1999 McGrath et al.         6,771,028 B1 82004 Sanford et al.           5.995,2789 A         9/1999 Stewart et al.         6,780,687 B2 82004 Sanford et al.           6.023,259 A         2/2000 Howard et al.         6,806,638 B2 10004 Lib. et al.           6.069,365 A         5/2000 Chow et al.         6,806,638 B2 102004 Shimoda           6.081,131 A         6/2000 Eshii         6,809,706 B2 10200 Shimoda           6.091,203 A         7/200 Kawashima et al.         6,861,670 B1 32005 Shimoda           6,144,222 A         11/2000 Holloman         6,873,310 B2 32005 Shimada           6,166,489 A         12/2000 Thompson et al.         6,873,320 B2 32005 Shimada           6,225,846 B1 5/2001 Wada et al.         6,990,114 B1 6/2005 Chuma           6,225,848 B1 5/2001 Sairo et al.         6,991,871 B2 6/2005 Chuma           6,225,948 B1 6/2001 Sairo et al.         6,991,871 B2 6/2005 Chuma           6,225,848 B1 6/2001 Sairo et al.         6,991,918 B2 6/2005 Chuma           6,230,928 B1 1/2								
S.880,582 A 3/1999   Sawada   6,738,034 B2   5/2004   Kaneko et al.								
5,903,248 A         5/1999         Irwin         6,738,035 Bz         52,004 Kantek et al.         5,917,38,035 Bz         52,004 Vinters           5,923,794 A         7/1999         McGrath et al.         6,771,028 Bl         8,2004 Vinters         3,900,629 A         11/1999 Yamada et al.         6,806,638 Bz         8,2004 Vinters         8,606,638 Bz         10/2004 Vinters         1,600,036,636         6,602,036,63 Az         2,000 Howard et al.         6,806,637 Bz         10/2004 Vinters         1,600,036,63         6,602,036,63 Az         2,000 Howard et al.         6,808,873 Bz         10/2004 Vinters         1,600,000,000         4,600,000         8,606,638 Bz         10/2004 Vinters         1,600,000								
5.917,280 A         61999 Burrows et al.         6,736,039 BH         82004 Winters           5.952,789 A         71999 McGrath et al.         6,777,712 BB         82004 Sanford et al.           5.952,789 A         91999 Stewart et al.         6,806,638 BZ         82000 Vankajima et al.           6,002,3259 A         22000 How and et al.         6,806,638 BZ         10/2004 Lih et al.           6,009,365 A         52000 Chow et al.         6,809,706 BZ         10/2004 Shimoda           6,091,203 A         7/2000 Kawashima et al.         6,806,137 BB         13/2005 Ohtani et al.           6,091,203 A         7/2000 Kawashima et al.         6,861,670 BB         13/2005 Ohtani et al.           6,144,222 A         11/2000 Ho         6,873,320 BS         3/2005 Ohtani et al.           6,167,838 A         12/2000 Hompson et al.         6,873,320 BS         3/2005 Ohuma           6,179,15 BI         11/2001 Beeteson et al.         6,909,114 BI         6/2005 Zavracky et al.           6,225,546 BI         5/2001 Wada et al.         6,919,871 BZ         7/2005 Kwon           6,224,546 BI         5/2001 Kane         6,937,215 BZ         8/2005 Kwon           6,225,248 BI         6/2001 Nishigaki         6,940,214 BI         9/2005 Komiya et al.           6,252,248 BI         10/2001 Kim         6,995,519								
5.923,794 A         7/1999         McGrath et al.         6,777,712 Bz         8/2004         Nanford et al.           5.952,789 A         9/1999         Stewart et al.         6,780,687 BZ         8/2004         Nakajima et al.           6.023,259 A         2/2000         Howard et al.         6,806,638 BZ         10/2004         Sempel et al.           6.081,131 A         6/2000 Eshi         6,809,706 BZ         10/2004         Shimoda           6.091,203 A         7/2000 Face of Shimoda         6,861,670 BI         3/2005         Oltani et al.           6.097,360 A         8/2000 Folloman         6,873,117 BZ         3/2005         Oltani et al.           6,144,222 A         11/2000 Folloman         6,873,117 BZ         3/2005         Oltani et al.           6,166,489 A         12/2000 Starnes et al.         6,873,320 BZ         3/2005         Nakamura           6,1229,508 BI         5/2001 Wada et al.         6,909,419 BZ         6/2005         Zavracky et al.           6,221,846 BI         5/2001 Saito et al.         6,909,419 BZ         6/2005         Zavracky et al.           6,222,508 BI         5/2001 Saito et al.         6,909,419 BZ         6/2005         Zavracky et al.           6,232,248 BI         6/2001 Sano et al.         6,940,214 BI         6/2000<								
S.952,789 A   9/1999   Stewart et al.   6,780,687 B2   8/2004   Nakajima et al.   6,806,837 B2   10/2004   Lih et al.   6,006,365 A   5/2000   Chow et al.   6,806,837 B2   10/2004   Sempel et al.   6,807,306 A   8/2000   Chow et al.   6,809,706 B2   10/2004   Shimoda   6,807,306 A   8/2000   Kawashima et al.   6,861,670 B1   3/2005   Ohtani et al.   6,907,306 A   8/2000   Holloman   6,873,3117 B2   3/2005   Ohtani et al.   6,144,222 A   11/2000   Holloman   6,873,3117 B2   3/2005   Ohtani et al.   6,144,222 A   11/2000   Holloman   6,873,3117 B2   3/2005   Ohtani et al.   6,145,326   Ohtani et al.   6,246,486   Ohtani et al.   6,246,486   Ohtani et al.   6,246,486   Ohtani et al.   6,246,487   Ohtani et al.   7,022,456   Ohtani et al.   0,246,487   O								
5,990,629 A 11/1999   Yamada et al.   6,806,638 B2   10/2004   Chow et al.   6,806,638 B2   10/2004   Shimoda   6,806,638 B2   10/2004   Shimoda   6,801,630 B2   10/2004   Shimoda   6,801,131 A   6/2000   Ishi   6,899,193 B1   2/2005   Yumoto   6,097,360 A   8/2000   Holloman   6,861,670 B1   3/2005   Ohtani et al.   6,873,171 B2   3/2005   Ohtani et al.   6,873,320 B2   3/2005   Ohtani et al.   6,873,330 B2   3/2005   Ohtani et al.   6,873,330 B2   3/2005   Ohtani et al.   6,166,489 A   12/2000   Thompson et al.   6,873,330 B2   3/2005   Ohtani et al.   6,166,489 A   12/2000   Thompson et al.   6,909,114 B1   6/2005   Zavracky et al.   6,225,846 B1   5/2001   Wada et al.   6,909,419 B2   6/2005   Zavracky et al.   6,225,846 B1   5/2001   Satio et al.   6,919,871 B2   7/2005   Kwon   6,232,939 B1   5/2001   Satio et al.   6,940,214 B1   9/2005   Komiya et al.   6,246,180 B1   6/2001   Nishigaki   6,943,500 B2   9/2005   LoChevalier   6,259,424 B1   7/2001   Kurogane   6,955,149 B2   10/2005   Bae et al.   6,288,696 B1   9/2001   Kurogane   6,955,647 B2   10/2005   Bae et al.   6,300,928 B1   10/2001   Kurogane   6,955,510 B2   2/2006   Adachi   6,300,928 B1   10/2001   Kim   7,022,556 B1   4/2006   Adachi   6,303,323 B1   10/2001   Yamazaki et al.   7,033,408 B2   4/2006   Adachi   6,303,323 B1   11/2001   Dawson et al.   7,023,408 B2   4/2006   Chen et al.   6,306,694 B1   10/2001   Yamazaki et al.   7,023,408 B2   4/2006   Chen et al.   6,323,332 B1   11/2001   Dawson et al.   7,103,808 B1   11/2001   Nishizawa et al.   7,129,917 B2   10/2005   Naugler   6,345,358 B1   2/2002   Sato et al.   7,129,917 B2   10/2006   Knape et al.   6,348,835 B1   2/2002   Sato et al.   7,129,917 B2   10/2006   Knape et al.   6,346,348 B1   1/2001   Nishizawa et al.   7,129,917 B2   10/2006   Knape et al.   6,346,348 B1   1/2001   Nishizawa et al.   7,248,236 B2   7/2007   Nakatian et al.   7,248,236 B								
6,023,259 A   2/2000   Howard et al.   6,806,857 B2   10/2004   Sempel et al.   6,806,836 B2   10/2004   Sempel et al.   6,806,837 B2   10/2004   Sempel et al.   6,806,837 B2   10/2004   Sempel et al.   6,809,138 B1   2/2005   Yumoto   6,091,203 A   7/2000   Kawashima et al.   6,859,193 B1   2/2005   Yumoto   6,091,203 A   7/2000   Kawashima et al.   6,859,193 B1   2/2005   Yumoto   6,144,222 A   11/2000   Ho   6,873,3117 B2   3/2005   Ohtani et al.   6,157,583 A   12/2000   Starnes et al.   6,878,968 B1   4/2005   Ohtani et al.   6,177,915 B1   1/2001   Beeteson et al.   6,909,141 B1   6/2005   Yamazaki   6,225,846 B1   5/2001   Wada et al.   6,909,419 B2   6/2005   Zavracky et al.   6,229,508 B1   5/2001   Kane   6,937,215 B2   8/2005   Lo   6,232,939 B1   5/2001   Kane   6,937,215 B2   8/2005   Lo   6,232,248 B1   6/2001   Saito et al.   6,943,500 B2   9/2005   Komiya et al.   6,244,6180 B1   6/2001   Sano et al.   6,943,500 B2   9/2005   Lo   Chevalier   6,252,248 B1   7/2001   Kurogane   6,954,194 B2   10/2005   Matsumoto et al.   6,303,963 B1   9/2001   Holloman   6,995,519 B2   2/2006   Murakami et al.   6,303,963 B1   10/2001   Ohtani et al.   7,023,408 B2   4/2006   Chen et al.   6,307,322 B1   10/2001   Ohtani et al.   7,023,408 B2   4/2006   Chen et al.   6,303,963 B1   10/2001   Ohtani et al.   7,023,408 B2   4/2006   Chen et al.   6,303,963 B1   10/2001   Ohtani et al.   7,023,408 B2   4/2006   Chen et al.   6,303,963 B1   10/2001   Ohtani et al.   7,023,408 B2   4/2006   Chen et al.   6,303,933 B1   11/2001   Ohtani et al.   7,023,408 B2   4/2006   Chen et al.   6,303,963 B1   10/2001   Ohtani et al.   7,023,408 B2   4/2006   Chen et al.   6,303,963 B1   10/2001   Ohtani et al.   7,023,408 B2   4/2006   Chen et al.   6,303,963 B1   10/2001   Ohtani et al.   7,023,408 B2   4/2006   Chen et al.   6,304,835 B1   1/2001   Ohtani et al.   7,104,835 B2   2/2006   Chen et al.   6,348,835 B1   1/2001   Ohtani et al.   7,129,914 B2   10/2006   Chen et al.   6,348,835 B1   1/2002   Sato et al.   7,129,914								
6,069,365 A 5/2000 Chow et al. 6,809,766 B2 10/2004 Shimoda 6,081,131 A 6/2000 Ishii 6,899,103 B1 2/2005 Winmoto 6,097,360 A 8/2000 Holloman 6,873,117 B2 3/2005 Obtani et al. 6,097,360 A 8/2000 Holloman 6,873,117 B2 3/2005 Ishizuka 6,144,222 A 11/2000 Ho 6,873,320 B2 3/2005 Nakamura 6,157,583 A 12/2000 Starnes et al. 6,909,114 B1 6/2005 Nakamura 6,166,489 A 12/2000 Thompson et al. 6,909,114 B1 6/2005 Vamazaki et al. 6,295,846 B1 5/2001 Wada et al. 6,909,114 B1 6/2005 Zavracky et al. 6,225,846 B1 5/2001 Wada et al. 6,919,871 B2 7/2005 Kwon 6,232,939 B1 5/2001 Saito et al. 6,919,871 B2 8/2005 Lo. 6,232,939 B1 5/2001 Saito et al. 6,943,500 B2 8/2005 Lo. 6,246,180 B1 6/2001 Sano et al. 6,943,500 B2 9/2005 Lo. 6,259,424 B1 7/2001 Kurogane 6,945,544 B2 10/2005 Matsumoto et al. 6,259,424 B1 7/2001 Kurogane 6,956,547 B2 10/2005 Matsumoto et al. 6,288,696 B1 9/2001 Holloman 6,995,510 B2 2/2006 Murakami et al. 6,303,963 B1 10/2001 Vimazaki et al. 6,995,510 B2 2/2006 Murakami et al. 6,306,694 B1 10/2001 Vimazaki et al. 6,995,510 B2 2/2006 Murakami et al. 6,306,694 B1 10/2001 Obtani et al. 7,023,408 B2 4/2006 Chen et al. 6,316,786 B1 11/2001 Usungan 6,325,323 B1 11/2001 Usungan 6,323,332 B1 11/2001 Vimazaki et al. 7,023,408 B2 4/2006 Chen et al. 6,316,786 B1 11/2001 Usunga 7,116,688 B2 10/2005 Sekiya et al. 6,348,835 B1 1/2001 Wimeller et al. 7,034,793 B2 4/2006 Chen et al. 6,3323,332 B1 11/2001 Vimazaki et al. 7,129,914 B2 10/2006 Chen et al. 6,348,835 B1 2/2002 Sato et al. 7,129,917 B2 10/2006 Cok obsilia et al. 7,129,918 B2 10/2006 Cok obsilia et al			2/2000	Howard et al.				
6,081,131 A 6/2000 Ishii 6,885,193 BI 2/2005 Viumoto 6,097,360 A 8/2000 Holloman 6,873,320 B2 3/2005 Ohtani et al. 6,097,360 A 8/2000 Holloman 6,873,320 B2 3/2005 Ishizuka 6,144,222 A 11/2000 Ho 6,873,320 B2 3/2005 Ishizuka 6,167,583 A 12/2000 Starnes et al. 6,878,968 BI 4/2005 Ohtani et al. 6,166,489 A 12/2000 Thompson et al. 6,909,114 BI 6/2005 Ohtanima 6,177,915 BI 1/2001 Beeteson et al. 6,909,114 BI 6/2005 Ohtanima 6,225,846 BI 5/2001 Wada et al. 6,909,114 BI 6/2005 Cwon 6,229,508 BI 5/2001 Kane 6,937,215 B2 8/2005 Lo 6,232,939 BI 5/2001 Kane 6,937,215 B2 8/2005 Lo 6,232,939 BI 5/2001 Saito et al. 6,940,214 BI 9/2005 Komiya et al. 6,246,180 BI 6/2001 Sano et al. 6,943,2500 B2 9/2005 Matsumoto et al. 6,252,248 BI 6/2001 Sano et al. 6,943,1500 B2 9/2005 Matsumoto et al. 6,254,244 BI 7/2001 Kurogane 6,954,194 B2 10/2005 Bae et al. 6,288,696 BI 9/2001 Holloman 6,995,510 B2 2/2006 Murakami et al. 6,303,963 BI 10/2001 Kim 7,022,556 BI 4/2006 Adachi 6,303,963 BI 10/2001 Ohtani et al. 7,023,408 B2 4/2006 Chen et al. 6,307,322 BI 10/2001 Duawson et al. 7,023,408 B2 4/2006 Cok 6,303,323 BI 10/2001 Duawson et al. 7,024,348 B2 4/2006 Cok 6,323,631 BI 11/2001 Cok et al. 7,034,793 B2 4/2006 Sekiya et al. 6,336,835 BI 1/2001 Duawson et al. 7,129,914 B2 10/2006 Naugler 6,323,631 BI 11/2001 Cok et al. 7,129,914 B2 10/2006 Naugler 6,3348,835 BI 1/2001 Vanazaki et al. 7,129,914 B2 10/2006 Naugler 6,3348,835 BI 1/2001 Vanazaki et al. 7,129,914 B2 10/2006 Naugler 6,3348,835 BI 1/2001 Vanazaki et al. 7,129,914 B2 10/2006 Naugler 6,3348,835 BI 1/2001 Vanazaki et al. 7,129,914 B2 10/2006 Naugler 6,334,835 BI 1/2001 Vanazaki et al. 7,129,914 B2 10/2006 Naugler 6,334,838 BI 8/2002 Vanazaki et al. 7,248,236 B2 7/2007 Nathan et al. 6,420,838 B2 7/2002 Vanazaki et al. 7,248,236 B2 7/2007 Nathan et al. 6,420,838 B2 7/2002 Vanazaki et al. 7,248,236 B2 7/2007 Nathan et al. 6,420,838 B1 7/2002 Vanazaki et al. 7,274,363 B2 9/2007 Ishizuka 6,443,3488 B1 8/2002 Vanazaki et al. 7,274,363 B2 9/2007 Ishizuka 6,445,376 B2 9/2002 Parrish 7,2000 Pa			5/2000	Chow et al.				
6,091,203 A 7/200 Kawashima et al. 6,861,670 B1 3,2005 Ohtani et al. 6,097,360 A 8/2000 Holloman 6,873,117 B2 3/2005 Salvamara et al. 6,144,222 A 11/2000 Ho 6,873,1320 B2 3/2005 Nakamura 6,157,583 A 12/2000 Starnes et al. 6,878,968 B1 4/2005 Ohtani et al. 6,157,915 B1 1/2001 Beeteson et al. 6,909,114 B1 6/2005 Zavracky et al. 6,225,846 B1 5/2001 Kane 6,919,871 B2 7/2005 Kwon 6,232,939 B1 5/2001 Kane 6,937,215 B2 8/2005 Lo 6,232,939 B1 5/2001 Saito et al. 6,943,500 B2 9/2005 Komiya et al. 6,259,424 B1 7/2001 Kurogane 6,943,500 B2 9/2005 Komiya et al. 6,259,424 B1 7/2001 Kurogane 6,956,547 B2 10/2005 Matsumoto et al. 6,259,424 B1 7/2001 Kurogane 6,956,547 B2 10/2005 Bae et al. 6,288,696 B1 9/2001 Holloman 6,995,510 B2 2/2006 Murakami et al. 6,300,928 B1 10/2001 Kim 7,022,556 B1 4/2006 G3,309,63 B1 10/2001 Kim 7,022,556 B1 4/2006 Chen et al. 6,306,694 B1 10/2001 Vamazaki et al. 7,027,015 B2 4/2006 Booth, Jr. et al. 6,307,322 B1 10/2001 Dawson et al. 7,027,015 B2 4/2006 Gooth, Jr. et al. 6,323,631 B1 11/2001 Cok et al. 7,034,793 B2 4/2006 Cok 6,323,631 B1 11/2001 Cok et al. 7,034,793 B2 4/2006 Gooth, Jr. et al. 6,345,885 B1 2/2002 Yeo et al. 7,116,588 B1 11/2001 Vamazaki et al. 7,116,588 B1 11/2001 Cok et al. 7,116,588 B1 11/2001 Vamazaki et al. 7,116,588 B1 11/2000 Vamazaki et al. 7,129,917 B2 10/2006 Vamazaki et al. 7,129,917 B2 10/2006 Vamazaki et al. 7,141,821 B1 11/2006 Vamazaki et al. 7,141,821 B1 11/2006 Vamazaki et al. 7,246,479 B2 10/2007 Vamazaki et al. 7,246,479 B2 10/2007 Vamazaki et al. 7,246,479 B2 10/2007 Vamazaki et al. 7,248,436 B2 7/2007 Vamazaki et al. 7,248,436 B		6,081,131 A	6/2000	Ishii				
6,194,222 A 11/2000 Ho 6,873,117 B2 3,2005 Ishizuka 6,144,222 A 11/2000 Ho 6,873,310 B2 3/2005 Nakamura 6,157,583 A 12/2000 Thompson et al. 6,878,968 B1 4/2005 Ohnuma 6,166,489 A 12/2000 Thompson et al. 6,909,114 B1 6/2005 Yamazaki 6,225,846 B1 5/2001 Wada et al. 6,909,419 B2 6/2005 Zavracky et al. 6,225,846 B1 5/2001 Kane 6,937,215 B2 8/2005 Lo 6,232,939 B1 5/2001 Saito et al. 6,904,214 B1 9/2005 Kwon 6,232,939 B1 5/2001 Nishigaki 6,943,500 B2 9/2005 Lo 6,246,180 B1 6/2001 Nishigaki 6,943,500 B2 9/2005 Lo 6,252,424 B1 7/2001 Kurogane 6,954,194 B2 10/2005 Matsumoto et al. 6,259,424 B1 7/2001 Kurogane 6,955,410 B2 10/2005 Matsumoto et al. 6,259,424 B1 7/2001 Kurogane 6,955,510 B2 2/2006 Murakami et al. 6,246,869 B1 10/2001 Kim 6,995,510 B2 2/2006 Murakami et al. 6,300,928 B1 10/2001 Kim 6,995,510 B2 2/2006 Arnold et al. 6,300,928 B1 10/2001 Kim 6,995,510 B2 2/2006 Adachi 6,303,963 B1 10/2001 Vamazaki et al. 7,022,556 B1 4/2006 Adachi 6,303,963 B1 10/2001 Vamazaki et al. 7,023,408 B2 4/2006 Chen et al. 6,306,694 B1 10/2001 Dawson et al. 7,023,408 B2 4/2006 Chen et al. 6,307,322 B1 10/2001 Dawson et al. 7,034,793 B2 4/2006 Sekiya et al. 6,323,631 B1 11/2001 Cok et al. 7,088,051 B1 8/2006 Cok 6,323,631 B1 11/2001 Unkeller et al. 7,088,051 B1 8/2006 Cok 6,323,631 B1 11/2001 Unkeller et al. 7,166,285 B2 10/2006 Sekiya et al. 6,345,085 B1 2/2002 Yeo et al. 7,116,058 B2 10/2006 Yamazaki et al. 7,129,917 B2 10/2006 Yamazaki et al. 7,141,821 B1 11/2000 Yamazaki et al. 7,245,277 B2 7/2007 Nakata 6,345,085 B1 7/2002 Yamazaki et al. 7,245,277 B2 7/2007 Nakata 6,420,758 B1 7/2002 Yamazaki et al. 7,245,277 B2 7/2007 Nakata 6,420,888 B1 7/2002 Yamazaki et al. 7,244,363 B2 9/2007 Ishizuka et al. 6,420,888 B1 7/2002 Parrish 12/2007 Parrish 7/2002 Parrish 12/		6,091,203 A	7/2000	Kawashima et al.				
6,144,222 A 11/2000 Ho 6,873,320 B2 3,2005 Nakamura 6,166,489 A 12/2000 Thompson et al. 6,878,968 B1 4/2005 Ohnuma 6,166,489 A 12/2000 Thompson et al. 6,909,419 B1 6/2005 Yamazaki 6,177,915 B1 1/2001 Beeteson et al. 6,909,419 B2 6/2005 Zavracky et al. 6,229,508 B1 5/2001 Kane 6,937,215 B2 8/2005 Lo 6,232,939 B1 5/2001 Saito et al. 6,919,871 B2 7/2005 Kwon 6,232,939 B1 5/2001 Saito et al. 6,940,214 B1 9/2005 Komiya et al. 6,246,180 B1 6/2001 Nishigaki 6,943,500 B2 9/2005 LeChevalier 6,252,248 B1 6/2001 Sano et al. 6,954,194 B2 10/2005 Matsumoto et al. 6,259,424 B1 7/2001 Kurogane 6,956,547 B2 10/2005 Matsumoto et al. 6,259,424 B1 7/2001 Kurogane 6,955,510 B2 2/2006 Matsumoto et al. 6,288,696 B1 9/2001 Holloman 6,995,510 B2 2/2006 Mrakami et al. 6,303,963 B1 10/2001 Ohtani et al. 7,023,3408 B2 4/2006 Chen et al. 6,306,694 B1 10/2001 Vamazaki et al. 7,023,408 B2 4/2006 G,303,363 B1 10/2001 Ohtani et al. 7,023,408 B2 4/2006 G,303,325 B1 11/2001 Dawson et al. 7,034,793 B2 4/2006 Sekiya et al. 6,316,786 B1 11/2001 Wueller et al. 7,088,051 B1 8/2006 Cok 6,323,331 B1 11/2001 Cok et al. 7,129,917 B2 10/2006 Maugler 6,323,832 B1 11/2001 Vamazaki et al. 7,129,917 B2 10/2006 Maugler 6,333,833 B1 11/2001 Vamazaki et al. 7,129,914 B2 10/2006 Cok 6,345,085 B1 2/2002 Yeo et al. 7,129,914 B2 10/2006 Maugler 6,345,085 B1 2/2002 Yeo et al. 7,129,914 B2 10/2006 Marga et al. 6,365,917 B1 4/2002 Yunazaki et al. 7,129,917 B2 10/2006 Marga et al. 6,365,917 B1 4/2002 Yunazaki et al. 7,129,917 B2 10/2006 Marga et al. 6,365,917 B1 4/2002 Yunazaki et al. 7,129,917 B2 10/2006 Marga et al. 6,373,453 B1 4/2002 Yunazaki et al. 7,129,917 B2 10/2006 Marga et al. 6,365,917 B1 4/2002 Yunazaki et al. 7,129,917 B2 10/2006 Marga et al. 6,365,917 B1 4/2002 Yunazaki et al. 7,129,917 B2 10/2006 Marga et al. 6,365,917 B1 4/2002 Yunazaki et al. 7,129,917 B2 10/2006 Marga et al. 6,399,88 B1 6/2002 Yamazaki et al. 7,246,479 B2 9/2007 Marga et al. 6,420,758 B1 7/2002 Marga et al. 7,243,453 B2 9/2007 Marga et al. 6,420,758 B1 7/2002 Marga et al. 7,243,453 B2		6,097,360 A	8/2000	Holloman				
6,157,383 A 12/2000 Starnes et al. 6,166,489 A 12/2000 Thompson et al. 6,177,915 B1 1/2001 Beeteson et al. 6,225,846 B1 5/2001 Wada et al. 6,225,846 B1 5/2001 Kane 6,232,939 B1 5/2001 Saito et al. 6,246,180 B1 6/2001 Saito et al. 6,246,180 B1 6/2001 Saito et al. 6,246,180 B1 6/2001 Saito et al. 6,252,48 B1 6/2001 Saito et al. 6,252,48 B1 6/2001 Saito et al. 6,259,424 B1 7/2001 Kurogane 6,259,424 B1 7/2001 Kurogane 6,256,47 B2 10/2005 Matsumoto et al. 6,274,887 B1 8/2001 Yamazaki et al. 6,230,928 B1 10/2001 Kim 6,303,963 B1 10/2001 Kim 6,303,963 B1 10/2001 Dhama 6,300,228 B1 10/2001 Dhama 6,307,322 B1 10/2001 Dawson et al. 6,307,322 B1 11/2001 Dawson et al. 7,023,408 B2 4/2006 Chen et al. 6,316,786 B1 11/2001 Juang 7,116,688 B2 9/2006 Naugler 6,323,333 B1 11/2001 Juang 7,116,688 B2 9/2006 Naugler 6,348,835 B1 2/2002 Sato et al. 7,129,914 B2 10/2006 Knapp et al. 7,129,914 B2 10/2006 Naugler 7,116,688 B2 10/2006 Sakiya et al. 7,129,914 B2 10/2006 Naugler 7,116,688 B2 10/2006 Sakiya et al. 7,129,917 B2 10/2006 Naugler 7,129,917 B2 10/2006 Naugler 7,134,837 B1 4/2002 Sato et al. 7,129,917 B2 10/2006 Naugler 7,134,837 B1 4/2002 Sato et al. 7,129,917 B2 10/2006 Naugler 7,134,837 B1 4/2002 Sato et al. 7,129,917 B2 10/2006 Soe et al. 7,129,917 B2 10/2006 Sakiya et al. 7,129,917 B2 10/2007 See et al. 7,245,277 B2 7/2007 Nakata 7,248,278 B2 9/2007 See et al. 7,248,278 B2 9/2007 Sakiya et al. 7,248,278 B2 9/2007 See		6,144,222 A	11/2000	Но				
6,160,489 A 12/2000			12/2000	Starnes et al.				
6,177,915 B1 5/2001 Wada et al. 6,909,419 B2 6/2005 Zavracky et al. 6,229,508 B1 5/2001 Kane 6,937,215 B2 8/2005 L0 6,232,939 B1 5/2001 Nishigaki 6,943,200 B2 9/2005 L0								
6,225,846 B1 5/2001 Kane 6,919,871 B2 7/2005 Kwon 6,232,939 B1 5/2001 Saito et al. 6,940,214 B1 9/2005 Komiya et al. 6,246,180 B1 6/2001 Nishigaki 6,943,500 B2 9/2005 Komiya et al. 6,252,248 B1 6/2001 Sano et al. 6,943,500 B2 9/2005 Komiya et al. 6,252,248 B1 6/2001 Kurogane 6,955,47 B2 10/2005 Matsumoto et al. 6,252,424 B1 7/2001 Kurogane 6,955,547 B2 10/2005 Matsumoto et al. 6,288,696 B1 9/2001 Holloman 6,995,510 B2 2/2006 Murakami et al. 6,303,963 B1 10/2001 Kirm 7,022,556 B1 4/2006 Chandle al. 7,023,408 B2 4/2006 Chandle al. 7,033,408 B2 4/2006 Chandle al. 7,034,793 B2 4/2006 Chandle al. 7,235,810 B1 6/2007 Shida et al. 7,245,277 B2 7/2007 Shida et al. 7,248,236 B2 7/2007 Nakata 6,392,617 B1 5/2002 Ghason 7,235,810 B1 6/2007 Shanazaki et al. 7,248,236 B2 7/2007 Nakata 6,420,834 B2 7/								
6,229,508 B1 5/2001 Saito et al. 6,937,215 B2 8/2005 Comiya et al. 6,246,180 B1 6/2001 Nishigaki 6,943,500 B2 9/2005 Comiya et al. 6,252,248 B1 6/2001 Sano et al. 6,954,194 B2 10/2005 Matsumoto et al. 6,259,424 B1 7/2001 Kurogane 6,956,547 B2 10/2005 Bae et al. 6,274,887 B1 8/2001 Yamazaki et al. 6,995,510 B2 2/2006 Murakami et al. 6,288,696 B1 9/2001 Holloman 6,995,510 B2 2/2006 Arnold et al. 6,300,928 B1 10/2001 Kim 7,022,556 B1 4/2006 Adachi 6,303,963 B1 10/2001 Ohtani et al. 7,023,408 B2 4/2006 Chen et al. 6,306,694 B1 10/2001 Dawson et al. 7,023,408 B2 4/2006 Cok 6,320,325 B1 11/2001 Dawson et al. 7,034,793 B2 4/2006 Sekiya et al. 6,320,325 B1 11/2001 Cok et al. 7,088,051 B1 8/2006 Cok 6,323,332 B1 11/2001 Vishizawa et al. 7,116,058 B2 10/2006 Naugler 6,323,631 B1 11/2001 Vishizawa et al. 7,129,914 B2 10/2006 Che et al. 6,348,835 B1 2/2002 Yeo et al. 7,129,914 B2 10/2006 Chapte et al. 6,348,835 B1 2/2002 Yeo et al. 7,129,914 B2 10/2006 Vamazaki et al. 6,365,917 B1 4/2002 Yamazaki 7,193,589 B2 3/2007 Voshida et al. 6,384,427 B1 5/2002 Vamazaki 7,193,589 B2 3/2007 Voshida et al. 6,399,988 B1 6/2002 Vamazaki et al. 7,245,277 B2 7/2007 Shen et al. 6,420,788 B1 7/2002 Shen et al. 7,248,236 B2 7/2007 Nakata 6,420,834 B2 7/2002 Vamazaki et al. 7,248,236 B2 7/2007 Nakata 6,420,838 B1 8/2002 Vamazaki et al. 7,274,345 B2 9/2007 Vamazaki et al. 6,420,838 B2 7/2002 Vamazaki et al. 7,274,345 B2 9/2007 Nakata 6,433,488 B1 8/2002 Vamazaki et al. 7,274,345 B2 9/2007 Vamazaki et al. 6,436,838 B1 8/2002 Vamazaki et al. 7,274,345 B2 9/2007 Vamazaki et al. 6,433,488 B1 8/2002 Parrish 7,2007 Jamazaki et al. 7,274,345 B2 9/2007 Vamazaki et al. 6,4468,638 B2 10/2002 Jamazaki et al. 7,274,345 B2 9/2007 Vamazaki et al. 6,445,376 B2 9/2007 Jamazaki et al. 7,274,345 B2 9/2007 Vamazaki et al. 6,4468,638 B2 10/2002 Jamazaki et al. 7,274,345 B2 9/2007 Vamazaki et al. 6,4468,638 B2 10/2002 Jamazaki et al. 7,274,345 B2 9/2007 Vamazaki et al. 6,4468,638 B2 10/2002 Jamazaki et al. 7,274,345 B2 9/2007 Vamazaki et al. 6,4468,638 B2 10/2002 J								
6,232,939 B1 5/2001 Nishigaki 6,940,214 B1 9/2005 Komiya et al. 6,246,180 B1 6/2001 Sano et al. 6,943,500 B2 9/2005 LeChevalier 6,252,248 B1 6/2001 Sano et al. 6,954,194 B2 10/2005 Bae et al. 6,259,424 B1 7/2001 Kurogane 6,956,547 B2 10/2005 Bae et al. 6,288,696 B1 9/2001 Holloman 6,995,510 B2 2/2006 Murakami et al. 6,300,928 B1 10/2001 Kim 7,022,556 B1 4/2006 Adachi 6,303,963 B1 10/2001 Ohtani et al. 7,022,556 B1 4/2006 Adachi 6,303,963 B1 10/2001 Ohtani et al. 7,023,408 B2 4/2006 Chen et al. 6,306,694 B1 10/2001 Jamazaki et al. 7,027,015 B2 4/2006 Booth, Jr. et al. 6,307,322 B1 10/2001 Dawson et al. 7,034,793 B2 4/2006 Cok 6,320,325 B1 11/2001 Mueller et al. 7,034,793 B2 4/2006 Cok 6,320,325 B1 11/2001 Juang 7,106,285 B2 9/2006 Naugler 6,323,631 B1 11/2001 Juang 7,116,058 B2 10/2006 Cok 63,323,631 B1 11/2001 Juang 7,116,058 B2 10/2006 Lo et al. 6,348,835 B1 2/2002 Yeo et al. 7,129,917 B2 10/2006 Lo et al. 6,348,835 B1 2/2002 Yeo et al. 7,129,917 B2 10/2006 Chapter al. 6,348,835 B1 2/2002 Yeo et al. 7,129,917 B2 10/2006 Yamazaki et al. 6,365,917 B1 4/2002 Yamazaki et al. 7,193,589 B2 3/2007 Yoshida et al. 6,334,427 B1 5/2002 Yamazaki et al. 7,209,97 B2 5/2007 Nakata 6,399,988 B1 6/2002 Yamazaki et al. 7,220,997 B2 5/2007 Nakata 6,399,988 B1 6/2002 Yamazaki et al. 7,248,236 B2 7/2007 Yamazaki et al. 6,414,661 B1 7/2002 Shen et al. 7,248,236 B2 7/2007 Yamazaki et al. 6,420,758 B1 7/2002 Nakajima 7,248,236 B2 7/2007 Yamazaki et al. 6,420,838 B1 7/2002 Azami et al. 7,274,345 B2 9/2007 Yamazaki et al. 6,433,488 B1 8/2002 Wamazaki et al. 7,274,345 B2 9/2007 Yamazaki et al. 6,433,488 B1 8/2002 Nakajima 7,248,236 B2 7/2007 Nathan et al. 6,433,488 B1 8/2002 Nakajima 7,243,456 B2 9/2007 Yamazaki et al. 6,443,488 B1 8/2002 Nakajima 7,244,345 B2 9/2007 Yamazaki et al. 6,443,488 B1 8/2002 Nakajima 7,274,345 B2 9/2007 Yamazaki et al. 6,443,488 B1 8/2002 Nakajima 7,274,345 B2 9/2007 Nathan et al. 6,443,488 B1 8/2002 Nakajima 7,274,345 B2 9/2007 Nathan et al. 6,445,476 B2 9/2002 Parrish 7,279,711 B1 10/2007 Yamazaki et al. 6,								
6,246,180 B1 6/2001 Nishigaki 6,943,500 B2 9/2005 LeChevalier 6,252,248 B1 6/2001 Sano et al. 6,954,194 B2 10/2005 Matsumoto et al. 6,259,424 B1 7/2001 Kurogane 6,956,547 B2 10/2005 Bae et al. 6,274,887 B1 8/2001 Yamazaki et al. 6,995,510 B2 2/2006 Murakami et al. 6,300,928 B1 10/2001 Kim 7,022,556 B1 4/2006 Adachi 6,303,963 B1 10/2001 Kim 7,022,556 B1 4/2006 Adachi 6,303,963 B1 10/2001 Ohtani et al. 7,023,408 B2 4/2006 Booth, Jr. et al. 6,306,694 B1 10/2001 Dawson et al. 7,027,015 B2 4/2006 Booth, Jr. et al. 6,316,786 B1 11/2001 Dawson et al. 7,034,793 B2 4/2006 Sekiya et al. 6,316,786 B1 11/2001 Dawson et al. 7,088,051 B1 8/2006 Cok 6,323,832 B1 11/2001 Cok et al. 7,106,285 B2 9/2006 Naugler 6,323,832 B1 11/2001 Juang 7,116,058 B2 10/2006 Lo et al. 6,345,085 B1 2/2002 Yeo et al. 7,129,914 B2 10/2006 Knapp et al. 6,345,085 B1 2/2002 Yeo et al. 7,129,917 B2 10/2006 Knapp et al. 6,345,085 B1 2/2002 Yeo et al. 7,129,917 B2 10/2006 Knapp et al. 6,345,085 B1 2/2002 Yeo et al. 7,141,821 B1 11/2006 Yamazaki et al. 6,365,917 B1 4/2002 Yamazaki et al. 7,193,589 B2 3/2007 Yoshida et al. 6,334,835 B1 2/2002 Yamazaki et al. 7,199,516 B2 4/2007 Seo et al. 6,334,427 B1 5/2002 Yamazaki et al. 7,220,997 B2 5/2007 Nakata 6,399,988 B1 6/2002 Yamazaki et al. 7,220,997 B2 5/2007 Nakata 6,399,988 B1 6/2002 Yamazaki et al. 7,245,277 B2 7/2007 Ishizuka 6,420,758 B1 7/2002 Nakajima 7,248,236 B2 7/2007 Nakata 6,420,758 B1 7/2002 Nakajima 7,244,345 B2 9/2007 Yamazaki et al. 6,433,488 B1 8/2002 Bu 7,274,345 B2 9/2007 Yamazaki et al. 6,433,488 B1 8/2002 Parrish 7,209,211 B1 10/2007 Yamazaki et al. 6,445,376 B2 9/2007 Parrish 7,279,711 B1 10/2007 Yamazaki et al. 6,445,376 B2 9/2002 Parrish 7,200,586 B2 12/2007 Oomori et al.		· · · · · ·						
6,259,424 B1 7/2001 Kurogane 6,956,547 B2 10/2005 Bae et al. 6,274,887 B1 8/2001 Yamazaki et al. 6,995,510 B2 2/2006 Murakami et al. 6,300,928 B1 10/2001 Kim 7,022,556 B1 4/2006 Adachi 6,303,963 B1 10/2001 Ohtani et al. 7,023,408 B2 4/2006 Chen et al. 6,307,322 B1 10/2001 Dawson et al. 7,027,015 B2 4/2006 Booth, Jr. et al. 6,307,322 B1 10/2001 Dawson et al. 7,034,793 B2 4/2006 Chen et al. 6,307,322 B1 11/2001 Mueller et al. 7,034,793 B2 4/2006 Sekiya et al. 6,323,331 B1 11/2001 Unang 7,116,0285 B2 9/2006 Naugler 6,323,631 B1 11/2001 Nishizawa et al. 7,106,285 B2 9/2006 Naugler 6,323,631 B1 11/2001 Nishizawa et al. 7,129,914 B2 10/2006 Lo et al. 6,345,085 B1 2/2002 Sato et al. 7,129,914 B2 10/2006 Marazaki et al. 6,348,835 B1 2/2002 Sato et al. 7,14,821 B1 11/2006 Yamazaki et al. 6,373,453 B1 4/2002 Yudasaka 7,193,589 B2 3/2007 Voshida et al. 6,384,427 B1 5/2002 Yamazaki et al. 7,220,997 B2 5/2007 Nakata 6,399,988 B1 6/2002 Yamazaki et al. 7,220,997 B2 5/2007 Nakata 6,399,988 B1 6/2002 Yamazaki et al. 7,248,236 B2 7/2007 Nakata 6,420,758 B1 7/2002 Shen et al. 7,248,236 B2 7/2007 Nakata 6,420,758 B1 7/2002 Yamazaki et al. 7,248,236 B2 7/2007 Nakata 6,420,758 B1 7/2002 Azami et al. 7,274,345 B2 9/2007 Nathan et al. 6,433,488 B1 8/2002 Bu 7,274,363 B2 9/2007 Ishizuka et al. 6,445,376 B2 9/2002 Parrish 7,274,345 B2 12/2007 Oomori et al.							9/2005	LeChevalier
6,2574,487 B1					6,954,194	B2	10/2005	Matsumoto et al.
6,288,696 B1 9/2001 Holloman 6,995,519 B2 2/2006 Arnold et al. 6,300,928 B1 10/2001 Kim 7,022,556 B1 4/2006 Adachi 7,023,408 B2 4/2006 Chen et al. 6,303,6694 B1 10/2001 Yamazaki et al. 7,023,408 B2 4/2006 Chen et al. 6,307,322 B1 10/2001 Dawson et al. 7,023,408 B2 4/2006 Sekiya et al. 6,316,786 B1 11/2001 Dawson et al. 7,034,793 B2 4/2006 Sekiya et al. 6,320,325 B1 11/2001 Cok et al. 7,088,051 B1 8/2006 Cok 6,323,332 B1 11/2001 Juang 7,116,058 B2 10/2006 Naugler 6,323,832 B1 11/2001 Nishizawa et al. 7,129,914 B2 10/2006 Lo et al. 6,345,085 B1 2/2002 Yeo et al. 7,129,917 B2 10/2006 Yamazaki et al. 6,365,917 B1 4/2002 Yamazaki 7,141,821 B1 11/2006 Yamazaki et al. 6,365,917 B1 4/2002 Yamazaki 7,193,589 B2 3/2007 Voshida et al. 6,384,427 B1 5/2002 Yamazaki et al. 7,129,916 B2 4/2007 Seo et al. 6,399,988 B1 6/2002 Yamazaki et al. 7,220,997 B2 5/2007 Nakata 6,399,988 B1 6/2002 Yamazaki et al. 7,224,277 B2 7/2007 Nakata 6,420,788 B1 7/2002 Nakajima 7,245,277 B2 7/2007 Nathan et al. 6,420,988 B1 7/2002 Vamazaki et al. 7,274,345 B2 9/2007 Yamazaki et al. 6,433,488 B1 8/2002 Bu 7,274,345 B2 9/2007 Vamazaki et al. 6,445,376 B2 9/2002 Parrish 7,279,711 B1 10/2007 Yamazaki et al. 6,468,638 B2 10/2002 Jacobsen et al. 7,299,711 B1 10/2007 Yamazaki et al. 6,468,638 B2 10/2002 Jacobsen et al. 7,200,971 B1 10/2007 Yamazaki et al. 6,468,638 B2 10/2002 Jacobsen et al. 7,279,711 B1 10/2007 Yamazaki et al. 6,468,638 B2 10/2002 Jacobsen et al. 7,200,971 B1 10/2007 Omori et al.					6,956,547	B2	10/2005	Bae et al.
6,300,928 B1 10/2001 Kim 7,022,556 B1 4/2006 Adachi 6,303,963 B1 10/2001 Ohtani et al. 7,023,408 B2 4/2006 Chen et al. 6,306,694 B1 10/2001 Dawson et al. 7,027,015 B2 4/2006 Booth, Jr. et al. 6,307,322 B1 10/2001 Dawson et al. 7,034,793 B2 4/2006 Sekiya et al. 6,316,786 B1 11/2001 Mueller et al. 7,034,793 B2 4/2006 Sekiya et al. 6,320,325 B1 11/2001 Cok et al. 7,106,285 B2 9/2006 Cok 6,320,325 B1 11/2001 Juang 7,116,058 B2 10/2006 Lo et al. 6,323,832 B1 11/2001 Nishizawa et al. 7,116,058 B2 10/2006 Lo et al. 6,345,085 B1 2/2002 Yeo et al. 7,129,914 B2 10/2006 Knapp et al. 6,348,835 B1 2/2002 Sato et al. 7,129,917 B2 10/2006 Knapp et al. 6,348,835 B1 2/2002 Sato et al. 7,141,821 B1 11/2006 Yamazaki et al. 6,365,917 B1 4/2002 Yamazaki 7,193,589 B2 3/2007 Yamazaki et al. 6,373,453 B1 4/2002 Yamazaki et al. 7,199,516 B2 4/2007 Seo et al. 6,399,988 B1 6/2002 Yamazaki et al. 7,220,997 B2 5/2007 Nakata 6,399,988 B1 6/2002 Yamazaki et al. 7,220,997 B2 5/2007 Nakata 6,399,988 B1 6/2002 Yamazaki et al. 7,245,277 B2 7/2007 Ishizuka 6,420,758 B1 7/2002 Nakajima 7,245,277 B2 7/2007 Ishizuka 6,420,888 B1 7/2002 Azami et al. 7,274,345 B2 9/2007 Ishizuka et al. 6,433,488 B1 8/2002 Bu 7,274,365 B2 9/2007 Ishizuka et al. 6,433,488 B1 8/2002 Bu 7,274,365 B2 9/2007 Ishizuka et al. 6,445,376 B2 9/2002 Parrish 7,279,711 B1 10/2007 Yamazaki et al. 6,468,638 B2 10/2002 Jacobsen et al. 7,304,621 B2 12/2007 Oomori et al.								
6,303,963 B1 10/2001 Ohtani et al. 7,023,408 B2 4/2006 Chen et al. 6,306,694 B1 10/2001 Yamazaki et al. 7,027,015 B2 4/2006 Booth, Jr. et al. 6,307,322 B1 10/2001 Dawson et al. 7,034,793 B2 4/2006 Cok 6,316,786 B1 11/2001 Mueller et al. 7,034,793 B2 4/2006 Cok 6,320,325 B1 11/2001 Cok et al. 7,106,285 B2 9/2006 Naugler 6,323,631 B1 11/2001 Juang 7,116,058 B2 10/2006 Lo et al. 6,323,832 B1 11/2001 Nishizawa et al. 7,129,914 B2 10/2006 Lo et al. 6,345,085 B1 2/2002 Yeo et al. 7,129,917 B2 10/2006 Knapp et al. 6,348,835 B1 2/2002 Sato et al. 7,129,917 B2 10/2006 Yamazaki et al. 6,365,917 B1 4/2002 Yamazaki 7,193,589 B2 3/2007 Yamazaki et al. 6,373,453 B1 4/2002 Yamazaki et al. 7,199,516 B2 4/2007 Seo et al. 6,392,617 B1 5/2002 Gleason 7,235,810 B1 6/2007 Vamazaki et al. 6,392,617 B1 5/2002 Gleason 7,235,810 B1 6/2007 Vamazaki et al. 6,420,758 B1 7/2002 Nakajima 7,248,236 B2 7/2007 Nakata 6,420,758 B1 7/2002 Vamazaki et al. 7,244,363 B2 7/2007 Nakajima 7,248,236 B2 7/2007 Nakajima 7,244,245 B2 9/2007 Ishizuka 6,433,488 B1 8/2002 Bu 7,274,345 B2 9/2007 Ishizuka 6,445,376 B2 9/2002 Parrish 7,279,711 B1 10/2007 Yamazaki et al. 6,433,488 B1 8/2002 Bu 7,274,363 B2 9/2007 Ishizuka et al. 6,445,376 B2 9/2002 Parrish 7,279,711 B1 10/2007 Yamazaki et al. 6,468,638 B2 10/2002 Jacobsen et al. 7,304,621 B2 12/2007 Oomori et al.								
6,306,694 B1 10/2001 Yamazaki et al. 7,027,015 B2 4/2006 Booth, Jr. et al. 6,307,322 B1 10/2001 Dawson et al. 7,034,793 B2 4/2006 Sekiya et al. 6,316,786 B1 11/2001 Mueller et al. 7,088,051 B1 8/2006 Cok 6,320,325 B1 11/2001 Cok et al. 7,106,285 B2 9/2006 Naugler 6,323,631 B1 11/2001 Juang 7,116,058 B2 10/2006 Lo et al. 6,323,832 B1 11/2001 Nishizawa et al. 7,129,914 B2 10/2006 Knapp et al. 6,345,085 B1 2/2002 Yeo et al. 7,129,917 B2 10/2006 Knapp et al. 6,348,835 B1 2/2002 Sato et al. 7,129,917 B2 10/2006 Yamazaki et al. 6,365,917 B1 4/2002 Yamazaki 7,193,589 B2 3/2007 Voshida et al. 6,3634,427 B1 5/2002 Yudasaka 7,199,516 B2 4/2007 Seo et al. 6,392,617 B1 5/2002 Gleason 7,235,810 B1 6/2007 Vamazaki et al. 6,399,988 B1 6/2002 Yamazaki 7,245,277 B2 7/2007 Nakata 6,420,758 B1 7/2002 Nakajima 7,248,236 B2 7/2007 Vamazaki et al. 6,420,834 B2 7/2002 Vamazaki et al. 7,274,345 B2 9/2007 Vamazaki et al. 6,433,488 B1 8/2002 Bu 7,274,363 B2 9/2007 Vamazaki et al. 6,433,488 B1 8/2002 Bu 7,274,363 B2 9/2007 Vamazaki et al. 6,445,376 B2 9/2002 Parrish 7,279,711 B1 10/2007 Vamazaki et al. 6,468,638 B2 10/2002 Jacobsen et al. 7,304,621 B2 12/2007 Oomori et al.								
6,307,322 B1 10/2001 Dawson et al. 7,034,793 B2 4/2006 Sekiya et al. 6,316,786 B1 11/2001 Mueller et al. 7,088,051 B1 8/2006 Cok 6,320,325 B1 11/2001 Cok et al. 7,106,285 B2 9/2006 Naugler 6,323,631 B1 11/2001 Juang 7,116,058 B2 10/2006 Lo et al. 6,323,832 B1 11/2001 Nishizawa et al. 7,129,914 B2 10/2006 Knapp et al. 6,345,085 B1 2/2002 Yeo et al. 7,129,917 B2 10/2006 Knapp et al. 6,348,835 B1 2/2002 Sato et al. 7,129,917 B2 10/2006 Knapp et al. 6,365,917 B1 4/2002 Yamazaki 7,193,589 B2 3/2007 Yoshida et al. 6,373,453 B1 4/2002 Yudasaka 7,199,516 B2 4/2007 Seo et al. 6,384,427 B1 5/2002 Gleason 7,220,997 B2 5/2007 Nakata 6,399,988 B1 6/2002 Yamazaki 7,235,810 B1 6/2007 Yamazaki et al. 6,399,988 B1 6/2002 Yamazaki 7,245,277 B2 7/2007 Nakata 6,414,661 B1 7/2002 Shen et al. 7,245,277 B2 7/2007 Nakata 6,420,758 B1 7/2002 Nakajima 7,245,277 B2 7/2007 Nakata 6,420,834 B2 7/2002 Yamazaki et al. 7,274,345 B2 9/2007 Vamazaki et al. 6,433,488 B1 8/2002 Bu 7,274,363 B2 9/2007 Imamura et al. 6,433,488 B1 8/2002 Bu 7,274,363 B2 9/2007 Vamazaki et al. 6,433,488 B1 8/2002 Bu 7,274,365 B2 12/2007 Ommori et al.								
6,316,786 B1 11/2001 Mueller et al. 7,088,051 B1 8/2006 Cok 6,320,325 B1 11/2001 Cok et al. 7,106,285 B2 9/2006 Naugler 6,323,631 B1 11/2001 Juang 7,116,058 B2 10/2006 Lo et al. 6,323,832 B1 11/2001 Nishizawa et al. 7,129,914 B2 10/2006 Knapp et al. 6,345,085 B1 2/2002 Yeo et al. 7,129,917 B2 10/2006 Knapp et al. 6,348,835 B1 2/2002 Sato et al. 7,129,917 B2 10/2006 Knapp et al. 6,365,917 B1 4/2002 Sato et al. 7,141,821 B1 11/2006 Yamazaki et al. 6,365,917 B1 4/2002 Yamazaki 7,193,589 B2 3/2007 Yoshida et al. 6,373,453 B1 4/2002 Yudasaka 7,199,516 B2 4/2007 Seo et al. 6,384,427 B1 5/2002 Gleason 7,220,997 B2 5/2007 Nakata 6,399,988 B1 6/2002 Yamazaki et al. 7,220,997 B2 5/2007 Nakata 6,399,988 B1 6/2002 Yamazaki 7,235,810 B1 6/2007 Yamazaki et al. 6,414,661 B1 7/2002 Shen et al. 7,245,277 B2 7/2007 Ishizuka 6,420,758 B1 7/2002 Nakajima 7,248,236 B2 7/2007 Nathan et al. 6,420,884 B1 7/2002 Azami et al. 7,274,345 B2 9/2007 Imamura et al. 6,433,488 B1 8/2002 Bu 7,274,363 B2 9/2007 Ishizuka et al. 6,433,488 B1 8/2002 Bu 7,274,365 B2 9/2007 Ishizuka et al. 6,433,488 B1 8/2002 Bu 7,274,363 B2 9/2007 Ishizuka et al. 6,445,376 B2 9/2002 Parrish 7,279,711 B1 10/2007 Yamazaki et al. 6,468,638 B2 10/2002 Jacobsen et al. 7,304,621 B2 12/2007 Oomori et al.		, , , , , , , , , , , , , , , , , , , ,						
6,329,325 B1 11/2001 Cok et al. 7,106,285 B2 9/2006 Naugler 6,323,631 B1 11/2001 Juang 7,116,058 B2 10/2006 Lo et al. 6,323,832 B1 11/2001 Nishizawa et al. 7,129,914 B2 10/2006 Knapp et al. 7,129,914 B2 10/2006 Knapp et al. 7,129,914 B2 10/2006 Yamazaki et al. 7,129,914 B2 10/2006 Knapp et al. 7,129,914 B2 10/2006 Yamazaki et al. 7,129,914 B2 10/2006 Knapp et al. 7,129,914 B2 10/2006 Yamazaki et al. 7,129,914 B2 10/2006 Yamazaki et al. 7,129,914 B2 10/2006 Yamazaki et al. 7,129,917 B2 10/2006 Yamazaki et al. 7,141,821 B1 11/2006 Yamazaki et al. 7,141,821 B1 11/2006 Yamazaki et al. 7,193,589 B2 3/2007 Yoshida et al. 7,199,516 B2 4/2007 Seo et al. 7,220,997 B2 5/2007 Nakata 7,220,997 B2 5/2007 Nakata 7,235,810 B1 6/2002 Yamazaki et al. 7,245,277 B2 7/2007 Ishizuka 7,245,277 B2 7/2007 Ishizuka 7,245,278 B1 7/2002 Yamazaki et al. 7,245,278 B2 7/2007 Nathan et al. 7,245,278 B1 7/2002 Yamazaki et al. 7,264,979 B2 9/2007 Ishizuka 6,420,988 B1 7/2002 Yamazaki et al. 7,274,345 B2 9/2007 Ishizuka et al. 6,433,488 B1 8/2002 Bu 7,274,363 B2 9/2007 Ishizuka et al. 6,433,488 B1 8/2002 Bu 7,274,365 B2 9/2007 Ishizuka et al. 6,445,376 B2 9/2002 Parrish 7,279,711 B1 10/2007 Yamazaki et al. 6,468,638 B2 10/2002 Jacobsen et al. 7,304,621 B2 12/2007 Oomori et al.								
6,323,631 B1 11/2001 Juang 7,116,058 B2 10/2006 Lo et al. 6,323,832 B1 11/2001 Nishizawa et al. 7,129,914 B2 10/2006 Knapp et al. 6,345,085 B1 2/2002 Sato et al. 7,129,917 B2 10/2006 Yamazaki et al. 6,365,917 B1 4/2002 Yamazaki 7,193,589 B2 3/2007 Yamazaki et al. 6,373,453 B1 4/2002 Yamazaki et al. 7,199,516 B2 4/2007 Seo et al. 6,384,427 B1 5/2002 Yamazaki et al. 7,220,997 B2 5/2007 Nakata 6,392,617 B1 5/2002 Gleason 7,235,810 B1 6/2007 Yamazaki et al. 6,399,988 B1 6/2002 Yamazaki 7,235,810 B1 6/2007 Yamazaki et al. 6,414,661 B1 7/2002 Shen et al. 7,245,277 B2 7/2007 Ishizuka 6,420,758 B1 7/2002 Nakajima 7,248,236 B2 7/2007 Nathan et al. 6,420,888 B1 7/2002 Yamazaki et al. 7,274,345 B2 9/2007 Ishizuka 6,433,488 B1 8/2002 Bu 7,274,345 B2 9/2007 Ishizuka 6,445,376 B2 9/2002 Parrish 7,279,711 B1 10/2007 Yamazaki et al. 6,433,488 B1 8/2002 Bu 7,279,711 B1 10/2007 Yamazaki et al. 6,468,638 B2 10/2002 Jacobsen et al. 7,304,621 B2 12/2007 Omori et al.		, ,			, ,			
6,323,832         B1         11/2001         Nishizawa et al.         7,1129,914         B2         10/2006         En et al.           6,345,085         B1         2/2002         Yeo et al.         7,129,917         B2         10/2006         Knapp et al.           6,348,835         B1         2/2002         Sato et al.         7,141,821         B1         11/2006         Yamazaki et al.           6,365,917         B1         4/2002         Yamazaki         7,193,589         B2         3/2007         Yoshida et al.           6,373,453         B1         4/2002         Yudasaka         7,199,516         B2         4/2007         Yoshida et al.           6,384,427         B1         5/2002         Yamazaki et al.         7,220,997         B2         5/2007         Nakata           6,392,617         B1         5/2002         Yamazaki et al.         7,220,997         B2         5/2007         Nakata           6,399,988         B1         6/2002         Yamazaki         7,245,277         B2         7/2007         Nathan et al.           6,420,758         B1         7/2002         Yamazaki et al.         7,248,236         B2         7/2007         Nathan et al.           6,420,988         B1								
6,345,085 B1 2/2002 Yeo et al. 7,129,917 B2 10/2006 Yamazaki et al. 6,348,835 B1 2/2002 Sato et al. 7,141,821 B1 11/2006 Yamazaki et al. 6,365,917 B1 4/2002 Yamazaki 7,193,589 B2 3/2007 Yoshida et al. 6,373,453 B1 4/2002 Yudasaka 7,199,516 B2 4/2007 Seo et al. 6,384,427 B1 5/2002 Yamazaki et al. 7,199,516 B2 4/2007 Seo et al. 6,392,617 B1 5/2002 Gleason 7,220,997 B2 5/2007 Nakata 6,399,988 B1 6/2002 Yamazaki 7,235,810 B1 6/2007 Yamazaki et al. 6,414,661 B1 7/2002 Shen et al. 7,245,277 B2 7/2007 Ishizuka 6,420,788 B1 7/2002 Nakajima 7,248,236 B2 7/2007 Nakajima 7,248,236 B2 7/2007 Vamazaki et al. 6,420,834 B2 7/2002 Yamazaki et al. 7,264,979 B2 9/2007 Vamazaki et al. 6,420,988 B1 7/2002 Azami et al. 7,274,345 B2 9/2007 Imamura et al. 6,433,488 B1 8/2002 Bu 7,274,363 B2 9/2007 Ishizuka et al. 6,445,376 B2 9/2002 Parrish 7,279,711 B1 10/2007 Yamazaki et al. 6,468,638 B2 10/2002 Jacobsen et al. 7,304,621 B2 12/2007 Omori et al.								
6,348,835 B1 2/2002 Sato et al. 7,141,821 B1 11/2006 Yamazaki et al. 6,365,917 B1 4/2002 Yamazaki 7,193,589 B2 3/2007 Yoshida et al. 6,373,453 B1 4/2002 Yudasaka 7,199,516 B2 4/2007 Seo et al. 6,384,427 B1 5/2002 Gleason 7,220,997 B2 5/2007 Nakata 63,399,988 B1 6/2002 Yamazaki et al. 7,245,277 B2 7/2007 Yamazaki et al. 6,414,661 B1 7/2002 Shen et al. 7,245,277 B2 7/2007 Ishizuka 6,420,758 B1 7/2002 Nakajima 7,248,236 B2 7/2007 Vamazaki et al. 6,420,888 B1 7/2002 Yamazaki et al. 7,243,458 B2 9/2007 Imamura et al. 6,433,488 B1 8/2002 Bu 7,274,363 B2 9/2007 Imamura et al. 6,433,488 B1 8/2002 Bu 7,274,363 B2 9/2007 Imamura et al. 6,435,376 B2 9/2002 Parrish 7,279,711 B1 10/2007 Yamazaki et al. 6,468,638 B2 10/2002 Jacobsen et al. 7,304,621 B2 12/2007 Omori et al.								
6,365,917 B1 4/2002 Yamazaki 7,193,589 B2 3/2007 Yoshida et al. 6,373,453 B1 4/2002 Yamazaki et al. 7,199,516 B2 4/2007 Seo et al. 6,384,427 B1 5/2002 Gleason 7,220,997 B2 5/2007 Nakata 6,399,988 B1 6/2002 Yamazaki et al. 7,235,810 B1 6/2007 Yamazaki et al. 6,414,661 B1 7/2002 Shen et al. 7,245,277 B2 7/2007 Ishizuka 6,420,758 B1 7/2002 Nakajima 7,248,236 B2 7/2007 Nathan et al. 6,420,884 B1 7/2002 Azami et al. 7,274,345 B2 9/2007 Ishizuka 6,433,488 B1 8/2002 Bu 7,274,363 B2 9/2007 Ishizuka 6,445,376 B2 9/2002 Parrish 7,279,711 B1 10/2007 Yamazaki et al. 6,436,638 B2 10/2002 Jacobsen et al. 7,304,621 B2 12/2007 Oomori et al.								
6,373,453       B1       4/2002       Yudasaka       7,193,389       B2       32007       Nosmate et al.         6,384,427       B1       5/2002       Yamazaki et al.       7,220,997       B2       5/2007       Nakata         6,392,617       B1       5/2002       Gleason       7,235,810       B1       6/2007       Yamazaki et al.         6,399,988       B1       6/2002       Yamazaki       7,245,277       B2       7/2007       Ishizuka         6,414,661       B1       7/2002       Shen et al.       7,248,236       B2       7/2007       Nathan et al.         6,420,758       B1       7/2002       Nakajima       7,264,979       B2       9/2007       Nathan et al.         6,420,988       B1       7/2002       Azami et al.       7,274,345       B2       9/2007       Imamura et al.         6,433,488       B1       8/2002       Bu       7,274,363       B2       9/2007       Ishizuka et al.         6,445,376       B2       9/2002       Parrish       7,279,711       B1       10/2007       Yamazaki et al.         6,468,638       B2       10/2002       Jacobsen et al.       7,304,621       B2       12/2007       Oomori et al.    <								
6,384,427 B1       5/2002 Yamazaki et al.       7,220,997 B2       5/2007 Nakata         6,392,617 B1       5/2002 Gleason       7,235,810 B1       6/2007 Yamazaki et al.         6,399,988 B1       6/2002 Yamazaki       7,235,810 B1       6/2007 Yamazaki et al.         6,414,661 B1       7/2002 Shen et al.       7,245,277 B2       7/2007 Nathan et al.         6,420,758 B1       7/2002 Yamazaki et al.       7,248,236 B2       7/2007 Nathan et al.         6,420,834 B2       7/2002 Yamazaki et al.       7,264,979 B2       9/2007 Yamagata et al.         6,420,988 B1       7/2002 Azami et al.       7,274,345 B2       9/2007 Immura et al.         6,433,488 B1       8/2002 Bu       7,274,363 B2       9/2007 Ishizuka et al.         6,445,376 B2       9/2002 Parrish       7,279,711 B1       10/2007 Yamazaki et al.         6,468,638 B2       10/2002 Jacobsen et al.       7,304,621 B2       12/2007 Omori et al.								
6,392,617 B1 5/2002 Gleason 7,225,810 B1 6/2007 Yamazaki et al. 6,399,988 B1 6/2002 Yamazaki 6,414,661 B1 7/2002 Shen et al. 7,245,277 B2 7/2007 Ishizuka 6,420,758 B1 7/2002 Nakajima 7,248,236 B2 7/2007 Vamazaki et al. 6,420,834 B2 7/2002 Yamazaki et al. 7,264,979 B2 9/2007 Yamagata et al. 6,420,988 B1 7/2002 Azami et al. 7,274,345 B2 9/2007 Imamura et al. 6,433,488 B1 8/2002 Bu 7,274,363 B2 9/2007 Ishizuka et al. 6,445,376 B2 9/2002 Parrish 7,279,711 B1 10/2007 Yamazaki et al. 6,468,638 B2 10/2002 Jacobsen et al. 7,304,621 B2 12/2007 Oomori et al.								
6,399,988 B1 6/2002 Yamazaki 7,253,810 B1 6/2007 Yamazaki et al. 6,414,661 B1 7/2002 Shen et al. 7,245,277 B2 7/2007 Ishizuka 6,420,788 B1 7/2002 Yamazaki et al. 7,248,236 B2 7/2007 Nathan et al. 6,420,834 B2 7/2002 Yamazaki et al. 7,264,979 B2 9/2007 Yamagata et al. 6,420,988 B1 7/2002 Azami et al. 7,274,345 B2 9/2007 Imamura et al. 6,433,488 B1 8/2002 Bu 7,274,363 B2 9/2007 Imamura et al. 6,445,376 B2 9/2002 Parrish 7,279,711 B1 10/2007 Yamazaki et al. 6,468,638 B2 10/2002 Jacobsen et al. 7,304,621 B2 12/2007 Oomori et al.								
6,414,661 B1       7/2002 Shen et al.       7,243,277 B2       7/2007 Ishizuka         6,420,758 B1       7/2002 Nakajima       7,248,236 B2       7/2007 Type       Nathan et al.         6,420,834 B2       7/2002 Yamazaki et al.       7,264,979 B2       9/2007 Yamagata et al.         6,420,988 B1       7/2002 Azami et al.       7,274,345 B2       9/2007 Imamura et al.         6,433,488 B1       8/2002 Bu       7,274,363 B2       9/2007 Ishizuka         6,445,376 B2       9/2002 Parrish       7,279,711 B1       10/2007 Yamazaki et al.         6,468,638 B2       10/2002 Jacobsen et al.       7,304,621 B2       12/2007 Oomori et al.								
6,420,758 B1       7/2002       Nakajima       7,248,236 B2       //2007       Nathan et al.         6,420,834 B2       7/2002       Yamazaki et al.       7,264,979 B2       9/2007       Yamagata et al.         6,420,988 B1       7/2002       Azami et al.       7,274,345 B2       9/2007       Imamura et al.         6,433,488 B1       8/2002       Bu       7,274,363 B2       9/2007       Ishizuka et al.         6,445,376 B2       9/2002       Parrish       7,279,711 B1       10/2007       Yamazaki et al.         6,468,638 B2       10/2002       Jacobsen et al.       7,304,621 B2       12/2007       Oomori et al.								
6,420,834 B2       7/2002 Yamazaki et al.       7,264,979 B2       9/2007 Yamagata et al.         6,420,988 B1       7/2002 Azami et al.       7,274,345 B2       9/2007 Imamura et al.         6,433,488 B1       8/2002 Bu       7,274,363 B2       9/2007 Ishizuka et al.         6,445,376 B2       9/2002 Parrish       7,279,711 B1       10/2007 Yamagata et al.         6,468,638 B2       10/2002 Jacobsen et al.       7,304,621 B2       12/2007 Omori et al.								
6,420,988 B1       7/2002 Azami et al.       7,274,345 B2       9/2007 Imamura et al.         6,433,488 B1       8/2002 Bu       7,274,363 B2       9/2007 Ishizuka et al.         6,445,376 B2       9/2002 Parrish       7,279,711 B1       10/2007 Yamazaki et al.         6,468,638 B2       10/2002 Jacobsen et al.       7,304,621 B2       12/2007 Omori et al.								
6,433,488 B1 8/2002 Bu 7,274,363 B2 9/2007 Ishizuka et al. 6,445,376 B2 9/2002 Parrish 7,279,711 B1 10/2007 Yamazaki et al. 6,468,638 B2 10/2002 Jacobsen et al. 7,304,621 B2 12/2007 Oomori et al.								
6,445,376 B2 9/2002 Parrish 7,279,711 B1 10/2007 Yamazaki et al. 6,468,638 B2 10/2002 Jacobsen et al. 7,304,621 B2 12/2007 Oomori et al.								
6,468,638 B2 10/2002 Jacobsen et al. 7,304,621 B2 12/2007 Oomori et al.								
6,489,952 B1 12/2002 Tanaka et al. 7,310,092 B2 12/2007 Imamura			10/2002	Jacobsen et al.				
		6,489,952 B1	12/2002	Tanaka et al.	7,310,092	B2	12/2007	Imamura

# US 9,070,775 B2 Page 3

(56)	Referen	ices Cited	2002/0190971 2002/0195967			Nakamura et al. Kim et al.
U.S.	PATENT	DOCUMENTS	2002/0195968			Sanford et al.
			2003/0020413			Oomura
7,315,295 B2		Kimura	2003/0030603 2003/0062524		2/2003	Shimoda Kimura
7,317,429 B2 7,319,465 B2		Shirasaki et al. Mikami et al.	2003/0002324			Kimura et al.
7,313,403 B2 7,321,348 B2		Cok et al.	2003/0076048			Rutherford
7,339,636 B2		Voloschenko et al.	2003/0090445			Chen et al.
7,355,574 B1		Leon et al.	2003/0090447 2003/0090481			Kimura Kimura
7,358,941 B2 7,385,224 B2*		Ono et al. Ishii et al 257/72	2003/0095087			Libsch
7,402,467 B1		Kadono et al.	2003/0107560			Yumoto et al.
7,414,600 B2		Nathan et al.	2003/0111966 2003/0122745			Mikami et al. Miyazawa
7,432,885 B2 7,474,285 B2		Asano et al. Kimura	2003/0122743			Yang et al.
7,485,478 B2		Yamagata et al.	2003/0151569		8/2003	Lee et al.
7,502,000 B2	3/2009	Yuki et al.	2003/0169219			LeChevalier
7,535,449 B2		Miyazawa	2003/0174152 2003/0179626			Noguchi Sanford et al.
7,554,512 B2 7,569,849 B2	6/2009 8/2009	Nathan et al.	2003/0197663			Lee et al.
7,619,594 B2	11/2009		2003/0206060		11/2003	
7,619,597 B2		Nathan et al.	2003/0230980 2004/0027063			Forrest et al. Nishikawa
7,697,052 B1 7,825,419 B2		Yamazaki et al. Yamagata et al.	2004/0027003			Shih et al.
7,859,492 B2	12/2010		2004/0066357	A1		Kawasaki
7,868,859 B2	1/2011	Tomida et al.	2004/0070557			Asano et al.
7,876,294 B2		Sasaki et al.	2004/0080262 2004/0080470		4/2004	Park et al. Yamazaki et al.
7,948,170 B2 7,969,390 B2		Striakhilev et al. Yoshida	2004/0090400		5/2004	
7,995,010 B2		Yamazaki et al.	2004/0108518		6/2004	
8,044,893 B2		Nathan et al.	2004/0113903 2004/0129933			Mikami et al. Nathan et al.
8,378,362 B2 8,493,295 B2		Heo et al. Yamazaki et al.	2004/0129933			Nathan et al.
8,497,525 B2		Yamagata et al.	2004/0135749	Al	7/2004	Kondakov et al.
2001/0002703 A1	6/2001	Koyama	2004/0145547		7/2004	
2001/0004190 A1		Nishi et al.	2004/0150592 2004/0150594		8/2004 8/2004	
2001/0013806 A1 2001/0015653 A1		Notani De Jong et al.	2004/0150595		8/2004	
2001/0020926 A1	9/2001		2004/0155841		8/2004	
2001/0026127 A1		Yoneda et al.	2004/0174347 2004/0174349		9/2004	Sun et al. Libsch
2001/0026179 A1 2001/0026257 A1	10/2001	Saeki Kimura	2004/01/4349		9/2004	
2001/0020237 A1 2001/0030323 A1	10/2001		2004/0189627		9/2004	
2001/0033199 A1	10/2001		2004/0196275		10/2004	
2001/0038098 A1 2001/0043173 A1	11/2001 11/2001	Yamazaki et al. Troutman	2004/0201554 2004/0207615		10/2004 10/2004	
2001/0045175 A1 2001/0045929 A1		Prache et al.	2004/0239596		12/2004	
2001/0052606 A1	12/2001		2004/0252089		12/2004	
2001/0052898 A1		Osame et al.	2004/0257355 2004/0263437		12/2004	Naugler Hattori
2002/0000576 A1 2002/0011796 A1		Inukai Koyama	2005/0007357		1/2005	Yamashita et al.
2002/0011799 A1		Kimura	2005/0035709			Furuie et al.
2002/0011981 A1		Kuijk	2005/0067970 2005/0067971		3/2005	Libsch et al.
2002/0015031 A1 2002/0015032 A1	2/2002	Fujita et al. Koyama et al.	2005/0068270			Awakura
2002/0013032 A1 2002/0030528 A1		Matsumoto et al.	2005/0088085	A1		Nishikawa et al.
2002/0030647 A1		Hack et al.	2005/0088103			Kageyama et al. Arnold et al.
2002/0036463 A1 2002/0047852 A1		Yoneda et al. Inukai et al.	2005/0110420 2005/0117096			Voloschenko et al.
2002/0047832 AT 2002/0048829 AT		Yamazaki et al.	2005/0140598	A1	6/2005	Kim et al.
2002/0050795 A1	5/2002	Imura	2005/0140610			Smith et al.
2002/0053401 A1		Ishikawa et al.	2005/0145891 2005/0156831		7/2005 7/2005	Abe Yamazaki et al.
2002/0070909 A1 2002/0080108 A1	6/2002	Asano et al. Wang	2005/0168416			Hashimoto et al.
2002/0084463 A1		Sanford et al.	2005/0206590			Sasaki et al.
2002/0101172 A1	8/2002		2005/0225686 2005/0260777			Brummack et al. Brabec et al.
2002/0101433 A1 2002/0113248 A1		McKnight Yamagata et al.	2005/0269959			Uchino et al.
2002/0113248 A1 2002/0122308 A1	9/2002		2005/0269960	A1	12/2005	Ono et al.
2002/0130686 A1	9/2002	Forbes	2005/0285822			Reddy et al.
2002/0154084 A1		Tanaka et al.	2005/0285825			Eom et al. Choi et al.
2002/0158823 A1 2002/0163314 A1		Zavracky et al. Yamazaki et al.	2006/0007072 2006/0012310			Choi et al.
2002/0180369 A1		Koyama	2006/0027807			Nathan et al.
2002/0180721 A1	12/2002	Kimura et al.	2006/0030084	A1	2/2006	
2002/0186214 A1		Siwinski	2006/0038758		2/2006	
2002/0190332 A1 2002/0190924 A1		Lee et al. Asano et al.	2006/0066527 2006/0092185		3/2006 5/2006	Chou Jo et al.
2002/0130324 AI	12/2002	roano et ar.	2000/0092103	2 X I	5/2000	so et ai.

(56)	Refere	nces Cited	EP GB	1 521 203 A		2005
	U.S. PATENT	DOCUMENTS	JP	2 205 431 09 090405	12/1 4/1	997
			JP JP	10-153759		998
2006/02325		Roy et al.	JP JP	10-254410 11 231805		998 999
2006/02618 2006/02641		Lee et al.	JP	11-282419	10/1	
2006/02739		Nathan et al.	JP	2000/056847		000
2006/02848		Yoon et al.	JP JP	2000-077192 2000-089198		000
2007/00019 2007/00019		Park et al. Hashimoto et al.	JP	2000-352941	12/2	
2007/00082		Park et al.	JP	2002-91376		002
2007/00461		Chin et al.	JP JP	2002-268576 2002-278513		002 002
2007/00699 2007/00809		Naugler et al. Takahara	JР	2002-278313	11/2	
2007/00809		Tanabe	JP	2003-022035		003
2007/00809		Nathan et al.	JP JP	2003-076331 2003-150082		0003 0003
2007/00809 2007/01034		Kawachi et al. Uchino et al.	JP	2003-170082		003
2007/01826	71 A1 8/2007	Nathan et al.	JP	2003-271095		003
2007/01877		Furuta et al 257/347	JP JP	2003-308046 2005-057217	10/2	003
2007/02732 2007/02853		Nagayama Ono	TW	485337		002
2007/02966	72 A1 12/2007	Kim et al.	TW	502233		002
2008/00429		Yamashita et al.	TW TW	538650 569173		003 004
2008/00552 2008/00744		Cok Ogura	WO	WO 94/25954	11/1	
2008/00885		Nathan et al.	WO	WO 9948079		999
2009/00328		Shinohara et al.	WO WO	WO 01/27910 A WO 02/067327 A		001 002
2009/00512		Cok et al.	WO	WO 03/034389 A		003
2009/01607 2009/02130		Tomida et al.	WO	WO 03/063124	7/2	003
2010/00525		Kinoshita	WO WO	WO 03/077231 WO 03/105117	9/2 12/2	003
2010/00797		Tanaka	wo	WO 2004/003877		004
2010/00973		Jung et al.	WO	WO 2004/034364		004
2010/01562 2010/03282		Tamura et al. Sasaki et al.	WO WO	WO 2005/022498 WO 2005/029455		005 005
2011/00902		Sasaki et al.	wo	WO 2005/025433 WO 2005/055185		005
2011/01808		Lee et al.	WO	WO 2006/053424		006
2012/02124		Govil	WO WO	WO 2006/063448 A WO 2006/137337	A 6/2 12/2	006
2013/00099 2013/00328		Cho et al. Chaji et al.	wo	WO 2007/003877		007
2013/01137			WO	WO 2007/079572		007
			WO	WO 2010/023270	3/2	010
		ENT DOCUMENTS		OTHER 1	PUBLIC	ATIONS
CA CA	2 249 592 2 368 386	7/1998 9/1999	Europe	ean Search Report for	European	Application No. EP 04 78
CA	2 242 720	1/2000		ated Mar. 9, 2009.		4 1' 1' N. ED 05 55
CA	2 354 018 2 436 451	6/2000 8/2002		ean Search Report for ated Oct. 30, 2009.	European	Application No. EP 05 75
CA CA	2 438 577	8/2002			European	Application No. EP 05 82
CA	2 483 645	12/2003	_	ated Mar. 27, 2009 (2	-	
CA CA	2 463 653 2498136	1/2004 3/2004	Europe	ean Search Report for	European	Application No. EP 07 71
CA	2522396	11/2004		ated May 20, 2009.		
CA	2443206	3/2005				26, 2012 in corresponding
CA CA	2472671 2567076	12/2005 1/2006	-	ean Patent Application led European Search R		led Apr. 27, 2011 issued dur-
CA	2526782	4/2006		*	-	lication No. 09733076.5 (13
CN	1381032	11/2002	pages)			`
DE 2 EP	0 2006 00542 0 940 796	6/2006 9/1999				tional Application No. PCT/
EP	1 028 471 A	8/2000		00180 dated Jul. 31, 20		
EP EP	1 103 947	5/2001		itional Search Report 1 04/001741 dated Feb. 2		tional Application No. PCT/
EP EP	1 130 565 A1 1 184 833	9/2001 3/2002				tional Application No. PCT/
EP	1 194 013	4/2002		05/001844 dated Mar. 2		
EP EP	1 310 939 1 335 430 A1	5/2003 8/2003				tional Application No. PCT/
EP	1 372 136	12/2003		05/001007 dated Oct. 1		tional Application No. PCT/
EP	1 381 019	1/2004		07/000652 dated Jul. 2:		понаг Аррисанон №. гСТ/
EP EP	1 418 566 1 429 312 A	5/2004 6/2004				tional Application No. PCT/
EP	1 439 520	7/2004		08/002307, mailed Apr		
EP	1 465 143 A	10/2004				tional Application No. PCT/ce, dated Apr. 16, 2012 (5
EP EP	1 467 408 1 517 290	10/2004 3/2005	pages)		atent OIII	oo, uatou Apr. 10, 2012 (3
			1 -0)			

### (56) References Cited

### OTHER PUBLICATIONS

International Search Report mailed Jul. 30, 2009 for International Application No. PCT/CA2009/000501 (4 pages).

Machine English translation of JP 2002-333862, 49 pages.

Nathan et al.: "Thin film imaging technology on glass and plastic" ICM 2000, Proceedings of the 12<sup>th</sup> International Conference on Microelectronics, (IEEE Cat. No. 00EX453), Tehran Iran; dated Oct. 31-Nov. 2, 2000, pp. 11-14, ISBN: 964-360-057-2, p. 13, col. 1, line 11-48; (4 pages).

Office Action issued in Chinese Patent Application 200910246264.4 Dated Jul. 5, 2013; 8 pages.

Patent Abstracts of Japan, vol. 1997, No. 08, Aug. 29, 1997, & JP 09 090405 A, Apr. 4, 1997 Abstract.

Patent Abstracts of Japan, vol. 1999, No. 13, Nov. 30, 1999, & JP 11 231805 A, Aug. 27, 1999 Abstract.

Patent Abstracts of Japan, vol. 2000, No. 09, Oct. 13, 2000—JP 2000 172199 A, Jun. 3, 2000, abstract.

Sanford, James L., et al., "4.2 TFT AMOLED Pixel Circuits and Driving Methods", SID 03 Digest, ISSN/0003, 2003, pp. 10-13.

Tatsuya Sasaoka et al., 24.4L; Late-News Paper: A 13.0-inch AM-OLED Display with Top Emitting Structure and Adaptive Current Mode Programmed Pixel Circuit (TAC)', SID 01 Digest, (2001), pp. 384.387

Zhiguo Meng et al; "24.3: Active-Matrix Organic Light-Emitting Diode Display implemented Using Metal-Induced Unilaterally Crystallized Polycrystalline Silicon Thin-Film Transistors", SID 01Digest, (2001), pp. 380-383.

\* cited by examiner

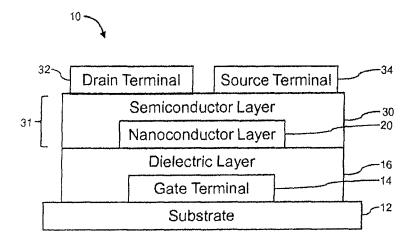


FIG. 1

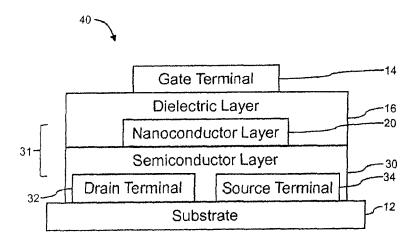


FIG. 2

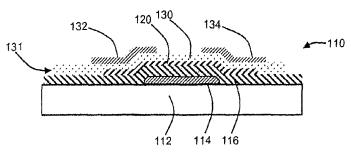


FIG. 3A

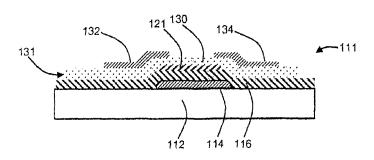
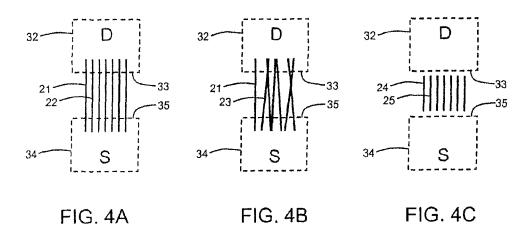


FIG. 3B



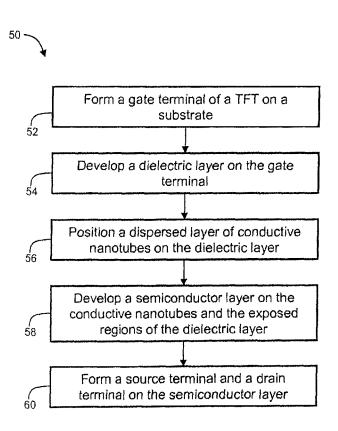


FIG. 5

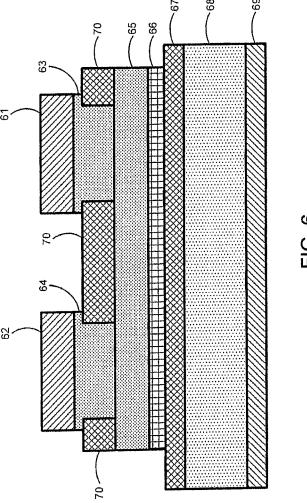
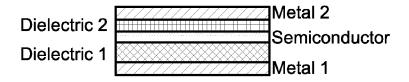
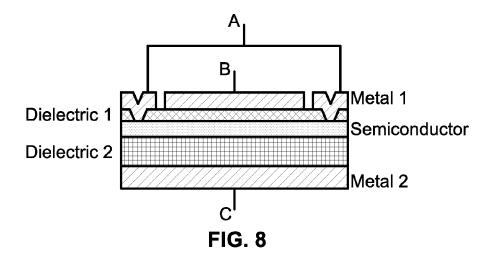


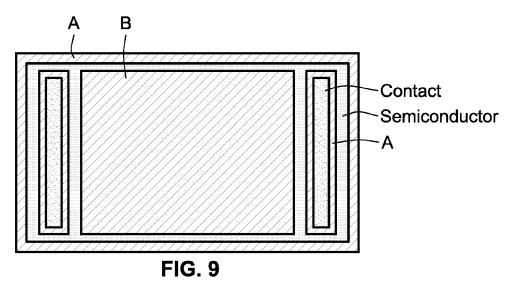
FIG. 6

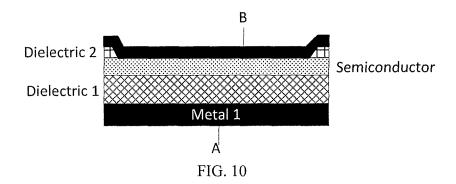




**FIG. 7** 







### 1

## THIN FILM TRANSISTOR

## CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of U.S. application Ser. No. 13/563,930, filed Aug. 1, 2012, now allowed, which claims the benefit of U.S. Provisional Application No. 61/514,887, filed Aug. 3, 2011, and claims the benefit of U.S. Provisional Applications Nos. 61/931,778, filed Jan. 27, 2014, and of 61/921,912, filed Dec. 30, 2013, all of which are hereby incorporated by reference herein in their entirety.

### FIELD OF THE INVENTION

The present disclosure generally relates to thin film transistors.

### **BACKGROUND**

Displays can be created from an array of organic light emitting devices ("OLEDs") each controlled by individual circuits (i.e., pixel circuits) having transistors for selectively controlling the circuits to be programmed with display information and to emit light according to the display information. Thin film transistors ("TFTs") fabricated on a substrate can be incorporated into such displays.

Mobility characterizes the responsiveness of a charge carrier in the presence of an electric field. Mobility is generally 30 expressed in units of cm<sup>2</sup>/V s. For transistors, the mobility of the channel region provides a measure of the performance of the transistor "on" current, e.g., the current that can be supplied by the transistor. In thin film transistors, a layer of semiconductor material is generally utilized to form the channel region.

Development of OLED display devices is challenged by the demand for a suitable drive transistor in the pixel circuits. Amorphous silicon (a-Si), the transistor channel material that sources the voltage to switch AM-LCD pixels, has a low  $^{40}$  mobility ( $\sim\!0.1~{\rm cm}^2~{\rm V}^{-1}~{\rm s}^{-1}$ ). Organic semiconductor channel materials are attractive for use as pixel circuit drive transistors for their homogeneity, low cost, and the variety of means by which they can be deposited, but their best mobilities are similar to that of a-Si. In a typical TFT architecture, low-mobility channel layers would require a large source-drain voltage to drive the necessary current. This consumes power in the transistor (as opposed to light production in the OLED), compromising the power savings.

P-type a-Si TFTs can have even lower mobility values, and  $\,$  50 can be as low as 0.01 cm  $^2$   $V^{-1}$  s  $^{-1}$  .

### **SUMMARY**

According to one embodiment, a thin film transistor comprises a semiconductor layer; first and second dielectric layers disposed on opposite sides of the semiconductor layer; a first metal layer forming first and second terminals on the opposite side of the first dielectric layer from the semiconductor layer, one of said first and second terminals extending 60 through said first dielectric layer into contact with the semiconductor layer, the first and second terminals and the first dielectric layer forming a capacitor; and a second metal layer forming a third terminal on the opposite side of the second dielectric layer from the semiconductor layer. In one implementation, the first and second terminals are source and drain terminals, and the third terminal is a gate terminal. The first

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metal layer may be divided to form the first and second terminals. The third terminal may be shared with one of the first and second terminals.

In another embodiment, a thin film transistor comprises a semiconductor layer; first and second dielectric layers disposed on opposite sides of the semiconductor layer, at least the second dielectric layer having openings therein; a first metal layer forming a first terminal on the opposite side of the first dielectric layer from the semiconductor layer; and a second metal layer forming a second terminal on the opposite side of the second dielectric layer from the semiconductor layer, with the second metal layer extending through the openings in the second dielectric layer to contact the semiconductor layer.

The foregoing and additional aspects and embodiments of the present invention will be apparent to those of ordinary skill in the art in view of the detailed description of various embodiments and/or aspects, which is made with reference to the drawings, a brief description of which is provided next.

### BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other advantages of the invention will become apparent upon reading the following detailed description and upon reference to the drawings.

FIG. 1 illustrates a block diagram of a bottom gate thin film transistor having a channel region including a nanoconductor layer.

FIG. 2 illustrates a block diagram of a top gate thin film transistor having a channel region including a nanoconductor layer.

FIG. 3A is a schematic illustration of a cross-section view of a thin film transistor 110 having a channel region including a nanoconductor layer.

FIG. 3B is a schematic illustration of a thin film transistor similar to the one illustrated in FIG. 3A, but with a shorter nanoconductor layer.

FIG. **4**A is a schematic illustration of a top view of a nanoconductor layer with a characteristic length exceeding the separation between the drain and source terminals of the TFT.

FIG. 4B is a schematic illustration of a top view of the nanoconductor layer similar to FIG. 4A, but where the individual nanoconductors are imperfectly aligned with a direction oriented from the drain terminal to the source terminal.

FIG. 4C is a schematic illustration of a top view of the nanoconductor layer similar to FIG. 4A, but where the characteristic length of the nanoconductor layer is less than the separation of the drain and source terminals of the TFT.

FIG. **5** is a flowchart illustrating an example process for manufacturing a thin film transistor having a channel region including a nanoconductor layer.

FIG. 6 is a diagrammatic cross section of a thin film transistor having a channel region including a nanoconductor layer.

FIG. 7 is a pair of sectional views of two typical Metal-Insulator-Metal (MIM) capacitors.

FIG. 8 is a sectional view of a structure having a high capacitance value.

FIG. 9 is a plan view of the structure shown in FIG. 8.

FIG. 10 is a sectional view of a modified structure having a high capacitance value.

While the invention is susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and will be described in detail herein. It should be understood, however, that the invention is not intended to be limited to the particular

forms disclosed. Rather, the invention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

### DETAILED DESCRIPTION

FIG. 1 illustrates a block diagram of a bottom-gate thin film transistor 10 having a channel region 31 including a nanoconductor layer 20. The thin film transistor 10 can generally be formed by deposition or a similar process on a substrate 12 of a display. For example, the substrate 12 can be a back plane substrate or an encapsulation glass substrate, or another suitable substrate providing a surface on which the TFT 10 can be developed. A gate terminal 14 is formed on the substrate 12. The gate terminal 14 is a conductive electrode for receiving signals to operate the TFT 10. The signals applied to the gate terminal 14 can be binary "high" or "low" signals turning the TFT 10 on or off or can be signals at a plurality of levels to control the amount of current conveyed through the drain and source terminals.

A dielectric layer 16 ("insulating layer") is developed over the gate terminal 14 to prevent current flow to or from the gate terminal 14 and the channel region 31 of the TFT 10. The dielectric layer 16 can be developed by a deposition process. A layer of nanoconductors, i.e., a nanoconductor layer 20, is 25 then placed ("positioned") on the dielectric layer 16. The nanoconductor layer 20 generally includes a plurality of nanoconductors and can include nanowires, nanofibers, and/or nanotubes, such as single-wall nanotubes ("SWNT"), double-wall nanotubes ("DWNT") and/or multi-wall nanotubes ("MWNT"). The nanoconductors can be formed of Carbon and/or Silicon and can optionally incorporate doping materials to modify the conductive properties of the nanoconductors. The nanoconductor layer 20 can be a single layer (i.e., monolayer) of nanoconductors.

A semiconductor layer 30 is developed over the nanoconductor layer 20. Together, the semiconductor layer 30 and the nanoconductor layer 20 form the two-layer channel region 31 of the TFT 10. For example, the semiconductor layer 30 can be made from organic or inorganic semiconductor materials. 40 The semiconductor layer 30 can be formed of, for example, amorphous silicon or polysilicon. The semiconductor layer 30 can also incorporate doping to modify the mobility characteristics of the TFT 10.

The drain terminal 32 and source terminal 34 of the TFT 45 are then formed on the semiconductor layer. The drain terminal 32 and the source terminal 34 are each formed of a conductive material suitable for conveying electrical energy. The terminals 32, 34 can be, for example, metallic. A channel separation distance is defined by the distance between the 50 drain terminal 32 and the source terminal 34. The channel separation distance is one parameter that influences the operation performance of the TFT 10.

The TFT 10 is referred to as a bottom-gate TFT because the gate 14 is formed directly on the substrate 12, and thus the 55 side of the TFT 10 having the gate 14 is referred to as a bottom side of the TFT 10, while the side of the TFT 10 having the drain and source terminals 32, 34 is referred to as a top side of the TFT 10.

FIG. 2 illustrates a block diagram of a top-gate thin film 60 transistor 40 having a channel region 31 including a nanoconductor layer 20. The top-gate TFT 40 is manufactured by applying the layered components discussed in connection with the bottom-gate TFT 10 shown in FIG. 1 in the reverse order. The drain terminal 32 and source terminal 34 are each 65 formed on the substrate 12. The semiconductor layer 30 is then deposited on the drain and source terminals 32, 34. The

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nanoconductor layer 20 is then applied to the semiconductor layer 30 to form the two-layer channel region 31. By applying the nanoconductor layer 20 to the surface of the semiconductor layer 30 opposite the drain and source terminals 32, 34, the nanoconductor layer 20 is positioned to lack any direct contact with the drain and source terminals 32, 34. Thus, during low field effect operation (e.g., low gate-source voltages), the performance of the TFT is dominated by the semiconductor layer because the nanoconductors lack any direct contact with the source or drain terminal of the TFT. The TFT therefore offers good leakage current performance, similar to the performance of the semiconductor layer 30. The dielectric layer 16 is then developed on the nanoconductor side of the channel region 31 and the gate terminal 14 is formed on the dielectric layer 16.

Moreover, the nanoconductors the nanoconductor layer can change the polarity of the TFT device. For example, carbon nanotubes have a p-type characteristic. An amorphous silicon (a-Si) TFT formed with its channel region including carbon nanotubes can therefore have a p-type characteristic. A p-type a-Si TFT so formed can be highly beneficial to a-Si TFT applications due to the enhanced mobility of such a p-type transistor compared to conventional p-type TFTs. The enhanced mobility of such a p-type transistor compared to conventional p-type TFTs can advantageously allow such p-type a-Si TFTs to be utilized in AMOLED display applications previously dominated by n-type TFTs and thereby enable p-type pixel circuit architectures.

FIG. 3A is a schematic illustration of a cross-section view of a thin film transistor 110 ("TFT") having a channel region 131 including a nanoconductor layer 120. In the schematic illustration in FIG. 3A, the components of the TFT 110 are numbered with reference numbers one-hundred higher than the corresponding components of the TFT 10 in the block 35 diagram of FIG. 1. The TFT 110 is formed on a substrate 112, which can be substrate of a display, such as a back plane substrate, a transparent planarization substrate, or an encapsulation glass substrate. A gate terminal 114 is formed on the substrate 112. The gate terminal 114 can be a conductive terminal with characteristics similar to the characteristics of the gate terminal 14 described in connection with FIG. 1. A dielectric layer 116 is developed on the gate terminal 114 to insulate the gate terminal 114 from the channel region 131 of the TFT 110. The dielectric layer 116 can be an electrical insulator.

The channel region 131 of the TFT has two layers: a nanoconductor layer 120 and a semiconductor layer 130. The semiconductor layer 130 separates the nanoconductor layer 120 from direct contact with the drain terminal 132 or the source terminal 134. The nanoconductor layer 120 generally includes a plurality of nanowires, nanofibers, and/or nanotubes. The individual nanoconductors ("nanoparticles") in the nanoconductor layer 120 are placed on the dielectric layer 116 in a thin film. The individual nanoconductors are each desirably aligned generally in a direction oriented from the drain terminal 132 to the source terminal 134 to increase the efficacy of charge transfer between the drain and source terminals 132, 134.

FIG. 3B is a schematic illustration of a thin film transistor 111 similar to the one illustrated in FIG. 3A, but with a shorter nanoconductor layer 121. The schematic illustration in FIG. 3B illustrates that the drain and source terminals 132, 134 can overlap the nanoconductor layer 121 by varying amounts. By adjusting the dimensional extent of the nanoconductor layer 121 along a direction oriented from the drain terminal 132 to the source terminal 134, the charge transfer characteristics of the two-layer channel region 131 can be modified. For

example, the two-layer channel region 131 can provide for relatively more charge transfer (e.g., increased mobility) by increasing the dimensional extent (e.g., length) of the nanoconductor layer 121, by increasing the density of nanoconductors within the nanoconductor layer 121, and/or by increasing the amount of overlap with the drain terminal 132 and/or source terminal 134. As discussed herein, the amount of overlap between the nanoconductor layer 121 and the drain and source terminals 132, 134 refers to the amount of surface area of the drain/source terminals 132, 134 which is separated from the nanoconductor layer 121 only by a vertical path through the semiconductor layer 130. In FIGS. 3A and 3B, the vertical direction through the semiconductor layer 130 is the direction outwardly normal to the substrate 112.

Aspects of the present disclosure further provide that the 15 nanoconductor layer 121 can be configured with a dimensional extent along the direction oriented from the drain terminal 132 to the source terminal 134 to not overlap either of the drain or source terminals 132, 134. For example, the length of the nanoconductor layer 121 can be less than the 20 separation distance between the drain terminal 132 and the source terminal 134. Additional configurations of the nanoconductor layer 121 are illustrated generally by the top view schematic illustrations in FIG. 4A through 4C.

FIG. 4A is a schematic illustration of a top view of a 25 nanoconductor layer with a characteristic length exceeding the separation between the drain and source terminals of the TFT. While the nanoconductor layer 20 is illustrated for schematic purposes with individual nanoconductors (e.g., the nanoconductors 21, 22) of uniform length and each aligned 30 between the drain terminal 32 and the source terminal 34, the present disclosure is no so limited. Aspects of the present disclosure apply to configurations with a nanoconductor layer 20 having individual nanoconductors of non-uniform length and orientation. The schematic illustration of the nanocon- 35 ductor layer 20 in FIG. 4A also illustrates that the individual nanoconductors (e.g., the nanoconductors 21, 22) are disposed in a monolayer. The nanoconductor layer 20 can be a dispersed monolayer of nanoconductors that covers less than a full cross-sectional area of the two-layer channel region. For 40 example, the gaps between the individual nanoconductors (e.g., the nanoconductors 21, 22) can be of roughly the same size as the widths of the nanoconductors themselves such that the individual nanoconductors (e.g., the nanoconductors 21, 22) in the nanoconductor layer 20 cumulatively cover 45 approximately half (e.g., 50%) of the two-layer channel region. In an implementation, any gaps between the individual nanoconductors (e.g., the nanoconductors 21, 22) are filled by the semiconductor layer deposited over the nanoconductor layer 20. The nanoconductor layer 20 can be imple- 50 mented with coverage of greater or lesser than 50% coverage, such as 30% coverage or 70% coverage. Generally, increasing the density of the monolayer of nanoconductors (e.g., the fraction of coverage) can increase the charge transfer characteristics of the two-layer channel region.

In FIGS. 4A through 4C, the hashed blocks labeled "D" and "S" represent the positions of the drain terminal 32 and source terminal 34, respectively. The drain terminal 32 has a channel side 33 and the source terminal 34 has a channel side 35. The distance between the channel side 33 of the drain 60 terminal 32 and the channel side 35 of the source terminal 34 can be referred to for convenience as a channel separation distance. As shown in FIG. 4A, the length of the nanoconductor layer 20 can be greater than the channel separation distance between the drain terminal 32 and the source terminal 34 such that the drain terminal 32 and the source terminal 34 each overlap at least a portion of the nanoconductor layer

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20. By overlapping at least a portion of the nanoconductor layer 20 with the drain/source terminals 32, 34, the nanoconductor layer 20 advantageously allows for a vertical connection path through the semiconductor layer to enhance the charge transfer characteristics of the two-layer channel region.

FIG. 4B is a schematic illustration of a top view of the nanoconductor layer similar to FIG. 4A, but where the individual nanoconductors (e.g, the nanoconductors 21, 23) are imperfectly aligned with a direction oriented from the drain terminal 32 to the source terminal 34. Because the nanoconductor layer 20 is not directly connected to either of the drain/source terminals 32, 34 (i.e., the nanoconductor layer 20 is connected to the drain/source terminals only through the semiconductor layer), the charge transfer characteristics of the two-layer channel region are relatively insensitive to precise alignment requirements of the individual nanoconductors (e.g., the nanoconductor 23). Thus, the nanoconductors (e.g., the nanoconductors 21, 23) generally enhance the effective mobility of the two-layer channel region by conveying charges to/from the drain/source terminals 32, 34 through the semiconductor layer such that the charge transfer characteristics of the thin film transistor is not limited by the mobility of the semiconductor laver.

FIG. 4C is a schematic illustration of a top view of the nanoconductor layer similar to FIG. 4A, but where the characteristic length of the nanoconductor layer is less than the separation of the drain and source terminals of the TFT. In the schematic illustration in FIG. 4C, the individual nanoconductors (e.g., the nanoconductors 24, 25) are illustrated as having a length less than the channel separation distance. In the configuration illustrated in FIG. 4C, the nanoconductor layer 20 does not overlap either the drain terminal 32 or the source terminal 34. Thus, a charge transfer path does not exist from the drain/source terminals 32, 34 to the nanoconductor layer 20 that includes only a vertical charge transfer path through the semiconductor layer. For example, in the configuration illustrated in FIG. 4C, the effective mobility of the two-layer channel region can be limited by the requirement that charges are transferred laterally through the

FIG. 5 is a flowchart 50 illustrating an example process for manufacturing a thin film transistor ("TFT") having a channel region including a nanoconductor layer. A gate terminal of a TFT is formed on a substrate in the first step 51. Next, a dielectric layer is developed on the gate terminal 54 in step 52. The dielectric layer coats the exposed surfaces of the gate terminal so as to prevent the two-layer channel region, which is deposited next, from directly contacting the gate terminal. A dispersed layer of nanoconductors, such as nanotubes or nanowires, are positioned on the dielectric layer in step 53. As discussed in connection with FIGS. 3A through 3C, the dispersed layer of nanoconductors can be a monolayer covering less than the full exposed area of the channel region. In step 54, a semiconductor layer is deposited on the nanoconductor layer and any exposed regions of the dielectric layer. The semiconductor layer can include amorphous silicon. The semiconductor layer and the nanoconductor layer thus jointly form the two-layer channel region. A source terminal and a drain terminal are then formed on the semiconductor layer in step 55. The source terminal and the drain terminal are thus formed so as to lack a direct connection with the nanoconductors

The flowchart **50** is an example of a process for manufacturing a bottom-gate TFT (i.e., the gate terminal is deposited on the substrate). However, a similar process can be adapted to manufacture a top-gate TFT having a two-layer channel region incorporating nanoconductors that do not directly con-

tact the drain or source terminals, such as the top-gate TFT 40 shown in FIG. 2. For example, a drain and a source terminal can be formed on a substrate. A semiconductor layer can be deposited over the drain and source terminals, and a nanoconductor layer can be placed over the semiconductor layer, 5 thus forming a two-layer channel region. A dielectric layer can be deposited over the two-layer channel region, and a gate terminal can be formed on the dielectric layer.

FIG. 6 illustrates a modified structure in which metallic source and drain terminals 61 and 62 (e.g., aluminum having 10 a thickness of about 100 nanometers) are formed on respective layers 63 and 64 of p+ silicon (e.g., with a thickness of about 35 nanometers). Directly beneath the layers 63 and 64 is a layer 65 of a semiconductor material (e.g., alternating nanocrystalline and amorphous silicon having a total thick- 15 ness of about 30 nanometers), which is deposited on top of a layer 66 of nanoconductors such as carbon nanotubes (e.g., with a thickness of about 1 to 2 nanometers). The nanoconductors are deposited on top of a dielectric layer 67 (e.g., thermal silicon dioxide with a thickness of about 100 nanom- 20 eters), which in turn is deposited on a substrate 68 (e.g., p+ silicon). The bottom surface of the substrate 67 is covered with a conductive back contact 69 (e.g., aluminum with a thickness of about 100 nanometers).

An exemplary process for forming the structure shown in 25 8. Separation of P using S/D Metal as hard mask. FIG. **6** is as follows:

- 1. Thermal P<sup>+</sup> Silicon Substrate Cleaning
  - (a) Ultrasonic cleaning of the substrate in acetone for 10 minutes, then in isopropyl alcohol (IPA) for another 10 minutes. This process is repeated twice.
  - (b) Substrate is rinsed with deionized water and dried with nitrogen. Note: The substrate is put on a hotplate (~90° C.) for 10 minutes before the next step.
- 2. Carbon nanotube coating
  - (a) Substrate treatment using amino-propyl tri-ethoxy 35 silane (APTES).
    - Before coating, the substrate is immersed into APTES solution (1% v/v in IPA) for 20 minutes, then the substrate is rinsed with IPA and dried with nitrogen.
  - (b) Dip coating carbon nanotubes on APTES-treated sub- 40 strate
    - The substrate is immersed into carbon nanotubes solution for 15 minutes.
    - Then the substrate is rinsed with abundant deionized water and dried with nitrogen.
    - The carbon nanotube-coated substrate is baked on a hotplate at 180° C. for 20 minutes before it is loaded into a plasma enhanced chemical vapor deposition (PECVD) cluster.
- 3. Nanocrystalline amorphous silicon (nc-Si) and SiNx depo- 50 sition using PECVD
  - (a) nc-Si (~30 nm.)

Gas:  $SiH_4/H_2=40/200$  sccm; Pr=900 mtorr;  $R_F=2$  W; T=210 C (set); Rate=4.07 nm/min.

(b) SiNx (150 nm)

Gas:  $SiH_4/NH_3/N_2=5/100/50$  sccm; Pr=1000 mtorr;  $R_E = 15 \text{ W}$ ; T=250 C (set); Rate=15 nm/min.

- 4. SiN, Via (Mask#1)
  - (a) Photolithography

Photoresist: NLOF 2035

Spin: 500 rpm for 10 seconds followed by 4000 rmp for 90 seconds.

Soft bake: 110° C. for 1 minute

Contact: low vacuum. Exposure: 5.4 seconds. Post-exposure bake: 110° C.

Develop: AZ300 MIF for ~30 seconds.

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(b) Wet etching SiN<sub>x</sub> using buffered hydrofluoric acid

The substrate is immersed in a BHF solution (10% v/v)for 27 seconds.

(c) Strip of Photoresist

The substrate is immersed in AZ KWIT stripper for 10 minutes, then rinsed by deionized water, acetone and

5. P<sup>+</sup> Deposition (~35 nm thickness)

Gas: SiH<sub>4</sub>/B<sub>2</sub>H<sub>6</sub>/H2=1.8/1.8/200 sccm; Pr=1500 mtorr;  $R_E = 65 \text{ W}$ ; T = 250 C, (set); Rate=7.7 nm/min.

6. S/D metal deposition (aluminum, ~100 nm thickness)

7. S/D patterning (Mask #1')

Photoresist: AZ 3312

Spin: 700 rpm for 10 seconds followed by 4000 rmp for 60

Soft bake: 90° C. for 1 minute.

Contact: low vacuum.

Exposure: 4 seconds.

Post-exposure bake: 120° C. for 1 minute.

Develop: AZ300 MIF for ~15 seconds.

Etching: ~3 minutes in PAN etchant at room temperature. Strip: Rinsed in AZ KWIT stripper for 4 minutes, then rinsed with deionized water, acetone and IPA.

RIE dry-etching P+ silicon:

 $R_F = 50 \text{ W}$ ;  $P_r = 20 \text{ mtorr}$ ;  $CF_4/H_2 = 20/3 \text{ sccm}$ ; rate =  $\sim 0.43$ nm/s

- 9. Device separation and isolation (Mask #2)
- (a) Photolithography

Photoresist: AZ 3312.

Spin: 700 rpm for 10 seconds followed by 4000 rmp for 60 seconds.

Soft bake: 90° C. for 1 minute.

Contact: low vacuum.

Exposure: 4 seconds.

Post-exposure bake: 120° C. for 1 minute.

Develop: AZ300 MIF for ~15 seconds.

(b) Dry-etching SiN,/Si/carbon nanotubes.

 $R_F = 125 \text{ W}$ ;  $P_r = 150 \text{ mtorr}$ ;  $CF_4/O_2 = 43/5 \text{ sccm}$ ; rate = -4nm/s.

- 10. Back Contact Metal Deposition (aluminum, ~100 nm thickness)
  - (a) Removal of back thermal oxide.

The wafer front side is protected by PR AZ3312 before it is immersed into BHF (10% v/v) for 4 minutes.

(b) Metal deposition on the back side of the wafer.

After the thermal oxide on the back side of the wafer is removed by BHF, the wafer is loaded into a vacuum chamber immediately for the metal deposition.

In FIG. 7, a capacitance is formed between a semiconductor layer and at least one of two metal layers located on opposite sides of the semiconductor layer. Each metal layer is separated from the semiconductor layer by a dielectric layer. The main challenge is that the semiconductor is very resistive and, therefore, the RC delay associated with charging the capacitor will be high, resulting in lower frame rate or hysteresis.

To avoid the high RC delay, a three-terminal capacitor is 60 used, as illustrated in FIGS. 8 and 9. The first metal layer, on one side of the semiconductor layer, is separated from the semiconductor layer by a first dielectric layer and forms a first terminal C that controls the resistivity of the semiconductor layer. The second metal layer, on the other side of the semi-65 conductor layer, is separated from the semiconductor layer by a second dielectric layer. The second metal layer is divided to form second and third terminals B and A, forming a capacitor

between terminals B and A. Terminal A extends through the second dielectric layer to contact the semiconductor layer.

In one example, terminal C is connected to a low or high voltage line in the panel, depending on the type of semiconductor (for example, low for p-type and high for n-type). In this case, the semiconductor layer resistance is significantly lowered by charge accumulation (or depletion). In another example, terminal C is shared with another terminal (B or A). In this case, one of those terminals has a voltage that reduces the resistance of the semiconductor material, depending on the type of the semiconductor.

In FIGS. **8** and **9** there are two contacts between the terminal A and the semiconductor layer, but one contact or more than two contacts can work as well (depending on the available area).

The order of layers can change, and FIGS. 8 and 9 show one example of the 3-terminal capacitor.

The voltage on the control terminal of the capacitor can be a fixed voltage or a toggling voltage. In the case of a toggling voltage, one can control the RC delay of charging and discharging the capacitance. For example, one can use a voltage that reduces the RC delay during charging of the capacitor, and then use a voltage for a holding period that makes the capacitance more stable. In this case, the characteristics of the capacitance are not changed significantly by a high voltage difference bias stress.

FIG. 10 shows another structure that provides a high capacitance value without adding extra processing steps to the fabrication. Since the second dielectric 2 is generally thicker than the semiconductor layer, the traditional way of having stacked dielectric results in a smaller capacitor than using stacked semiconductor and dielectric. Here, the second dielectric is etched during patterning of that dielectric layer, and then the metal for the electrode B is deposited to make contact with the semiconductor layer through openings in the pattern. To have consistent capacitance, the electrodes B and A can be connected in a way that the voltage across the two electrodes A and B is always higher or lower than the threshold voltage of the formed metal-insulator-semiconductor capacitor. Thus, the semiconductor layer will always act as an insulator or conductor layer.

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While particular embodiments and applications of the present invention have been illustrated and described, it is to be understood that the invention is not limited to the precise construction and compositions disclosed herein and that various modifications, changes, and variations can be apparent from the foregoing descriptions without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A thin film capacitor comprising

a semiconductor layer having a controllable resistance, first and second dielectric layers disposed on opposite sides of the semiconductor layer,

- a first metal layer forming first and second terminals on the opposite side of the first dielectric layer from the semi-conductor layer, said first terminal extending through said first dielectric layer into contact with the semiconductor layer, said second terminal not contacting said semiconductor layer
- a second metal layer forming a third terminal on the opposite side of the second dielectric layer from the semiconductor layer; and
- a voltage source coupled to one of said second and third terminals for reducing the resistance of said semiconductor layer, and the other of said second and third terminals forming a capacitor with said semiconductor layer.
- 2. The thin film capacitor of claim 1, wherein the first and second terminals are source and drain terminals, and said third terminal is a gate terminal.
- 3. The thin film capacitor of claim 1 in which said first metal layer is divided to form said first and second terminals.
- **4**. The thin film capacitor of claim **1** in which said third terminal is shared with one of said first and second terminals.
- 5. The thin film capacitor of claim 1 in which said second and third terminals are connected, and a capacitor is formed between said semiconductor layer and said second and third terminals.
- **6**. The thin film capacitor of claim **1** in which a source of a toggling voltage is connected to a terminal of said thin-film capacitor.

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